

Read Young Scientists at Work

# CHEMISTRY



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### Editorial:

Essential Resources

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A SCIENCE SERVICE PUBLICATION

## *Essential Resources*

► YOUNG AMERICANS able and willing to take their places in the laboratories of our country are a resource not to be wasted by those whose decisions will decide our future destiny. It is important that their training not be interrupted. If our country is to maintain its leadership in technical methods, training our youth in the fundamentals of science is more important than mere military drill, and should be so recognized by those who plan selective service.

Throughout history, well-drilled manpower has marched to defeat at the hands of men who used brain power for survival. The strength of our scientific civilization lies in brains well trained in original, independent thinking. They are needed to harness the new forces of atomic energy recently released by scientists who were so trained in their youth.

If our beginnings in understanding these new forces are locked away under the cloak of "secrecy" and allowed to stagnate, freer peoples will make the discoveries denied our researchers by the fears of those who do not understand the way science develops. Military secrecy has a long history, and has developed into a code which must take the chance of at least "one traitor in every fort."

Exchange of scientific information by those competent to utilize it is an entirely different plane of operation. If we are ever to rise beyond a race for annihilation in our use of nuclear forces, it is imperative that teen-age boys and girls be inducted now into the techniques that keep our scientific civilization going. Long apprenticeship is necessary to learn these skills. More fundamentally, it is necessary to keep youthful curiosity burning. They must have the satisfaction of knowing that they can pursue new ideas wherever they may lead, and the hope that their efforts will accomplish something for the betterment of mankind.

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March 1951

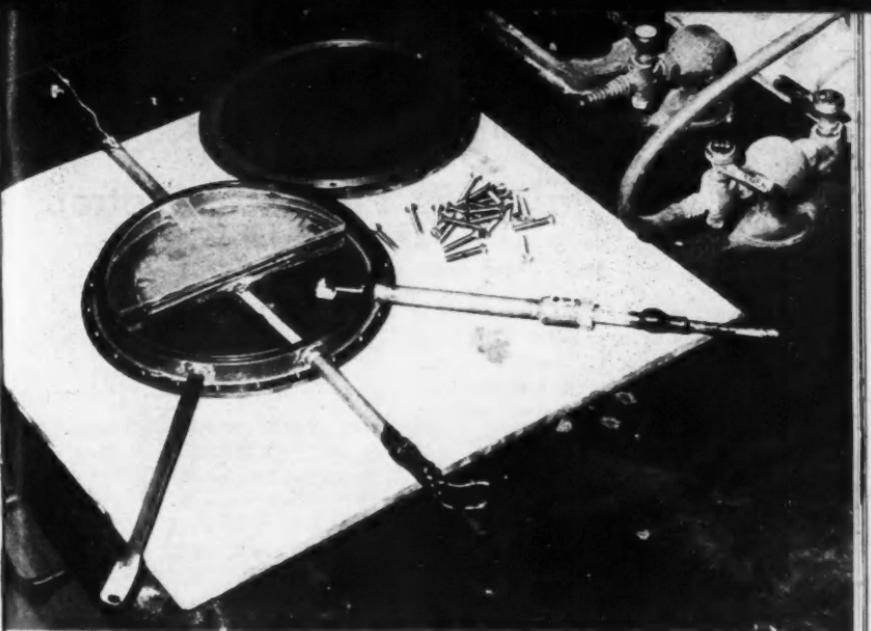
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► DEES of the cyclotron built by Robert Edmund Simpson, high school senior of Kenmore, N. Y., and submitted as his science project in the Tenth Annual Science Talent Search. A copper pipe leads to the dee, while the other dee is formed by the vacuum chamber itself, shown opened. The other lead-in tubes are for the hydrogen admission and filament, the target probe and the connection to the vacuum pump.

## Young Scientists at Work

► YOUNG AMERICA is learning to use the tools of atomic science. A Wilson Cloud Chamber, a Beta-ray Counter and a Cyclotron, which until recently were among the gear of abstruse physics, were built by high school boys for this year's Science Talent Search. Another lad tries his hand at making organic chemicals never synthesized before. Other fields of science, astronomy, geology, biology, electronics and mathematics, claim the attention of this year's Famous Forty.

Last December, scientifically minded high school seniors for the tenth successive year entered the nationwide Science Talent Search, administered by Science Service. They competed for the Westinghouse Science Talent Search Scholarships.

Essays of four of this year's top forty winners appear in this issue of CHEMISTRY, with photographs of the boys and their exhibits at the Science Talent Institute in Washington.

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Science Talent Search  
Essay and Project, 1951

## A One-half Mev Proton Cyclotron

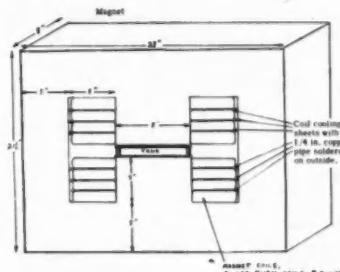
by ROBERT EDMUND SIMPSON

Kenmore Senior High School, Kenmore, N. Y.

LAST APRIL I became interested in the possibility of constructing a small cyclotron under the auspices of the school which I attend, Kenmore Senior High School. I immediately began to study the matter, reading many references on the subject. Especially helpful were the articles written by Dr. E. O. Lawrence in the *Physical Review*. I organized the material I had gathered and drew up a tentative set of plans for a one-half million electron-volt machine. I wrote a letter to Dr. Lawrence which included my plans. I received a very cordial reply from him and was glad to hear that my plans were sound. The suggestions enclosed in Dr. Lawrence's letter proved very helpful.

### Magnet and Coils

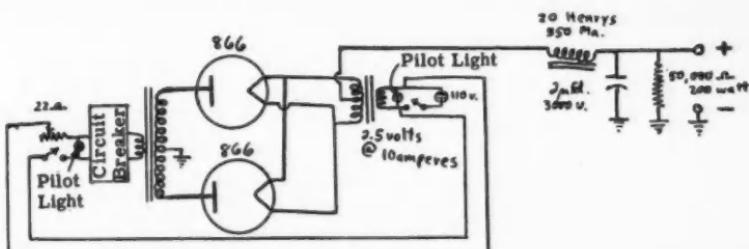
The school was indeed fortunate in the gift of the laminations that, when assembled, formed an 800 pound magnet with pole faces eight inches in diameter. My father and I stacked the three thousand odd pieces into the complete magnet in three nights. The magnet is held together by an angle-iron frame bolted in eight places. By calculations shown in the Appendix, I figured that I would need 5,000 turns of No. 14 wire or 200 pounds for the magnet coils. Fortunately the school was able to purchase for a nominal price this amount of wire. During the summer between my junior and senior year, with the help of another



student, I wound eight doughnut-shaped coils of 625 turns apiece on the lathe in the school's electric shop. Unfortunately six of the coils were either too thick or came loose and had to be wound a second time. Only about six feet of wire was left over after all eight coils were wound. Each coil was thoroughly shellacked as it was wound, thus resulting in a hard coil when the shellac dried. As an additional precaution each coil was securely taped.

Two 150-volt direct current generators were connected in series to supply the current for the coils. By a simple application of Ohm's law, 300 volts will drive eight amperes through the coils, since their resistance is 37.5 ohms. Because I am overloading the wire with respect to current carrying capacity, I inserted six copper cooling sheets, doughnut-shaped with  $\frac{1}{4}$  inch copper pipe soldered around the outside of each sheet. Cold water is

## Power Supply

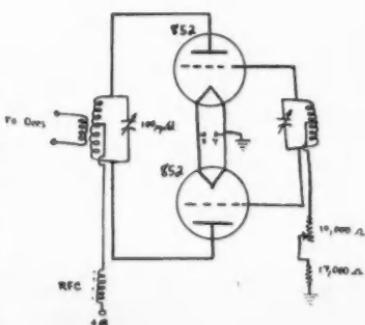


run through this pipe when the magnet is in operation. I have run the magnet for periods of about one hour and the coils have not heated up sufficiently to damage them. Thus, with eight amperes flowing through 5,000 turns of wire, I have 40,000 ampere-turns.

### Oscillator and Power Supply

To supply the radio-frequency power on the dees I had to build an oscillator complete with a power supply. At first I was in doubt as to how much power I would need, and so I designed a unit capable of delivering about two kilowatts, using four 304TL's in push-pull parallel.

Oscillator

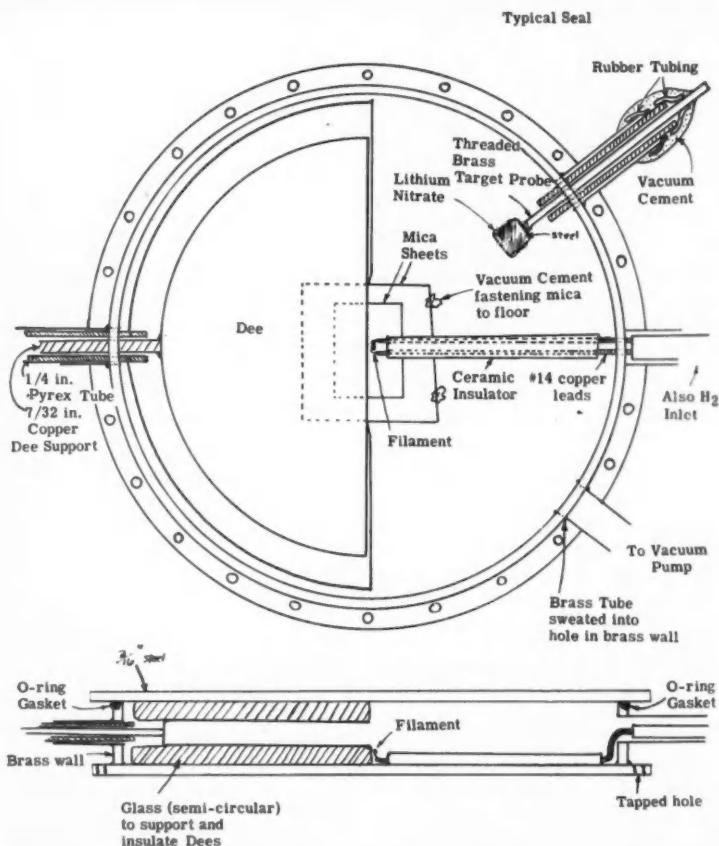


I later learned from Dr. Lawrence's letter that I would need only  $\frac{1}{2}$  of the power of the original oscillator which could easily be obtained from a single 304TL. However, at that time the 304TL's were not available, so I had to design an oscillator using two 852's which I already had. This unit delivers about 250 watts which should be sufficient to produce a proton beam. This is the oscillator shown in the photograph\* lighting the fluorescent light.

I spent some three weeks after school and at night in building the power supply and the oscillator. The 20:1 transformer used to supply the plate voltage draws too much current to merely connect it to a 110 volt line; I therefore put a variable resistor in series with the transformer's primary winding. This prevents the tripping of the circuit breaker, but the voltage on the secondary winding is consequently lowered from 2,200 volts to 1,600 volts since the primary voltage is lowered to 80 volts. The reason why the power supply has only one choke-condenser section is purely one of expense. I am now making a new oscillator using a single

\* See Back Cover photograph.

Details of the Vacuum Chamber and Associated Apparatus



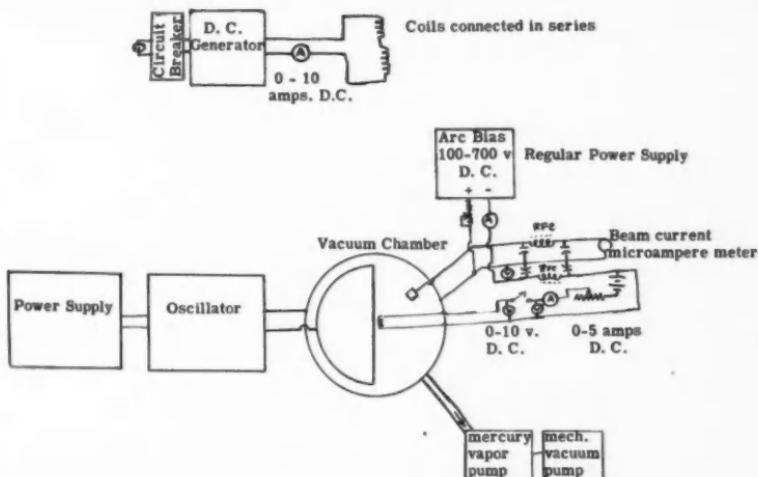
304TL which should deliver one kilowatt.

### The Vacuum Chamber

The vacuum chamber, which was made to my specifications by a friend of my father's who has a complete machine shop, consists of two circular

3/16 inch steel plates nine inches in diameter butting against a circular wall of  $\frac{1}{8}$  inch brass. The bottom steel plate was soldered to the brass wall, while the top one was sealed to the wall by being compressed against an O-ring rubber gasket by

Schematic Diagram of the Layout of the Component Parts



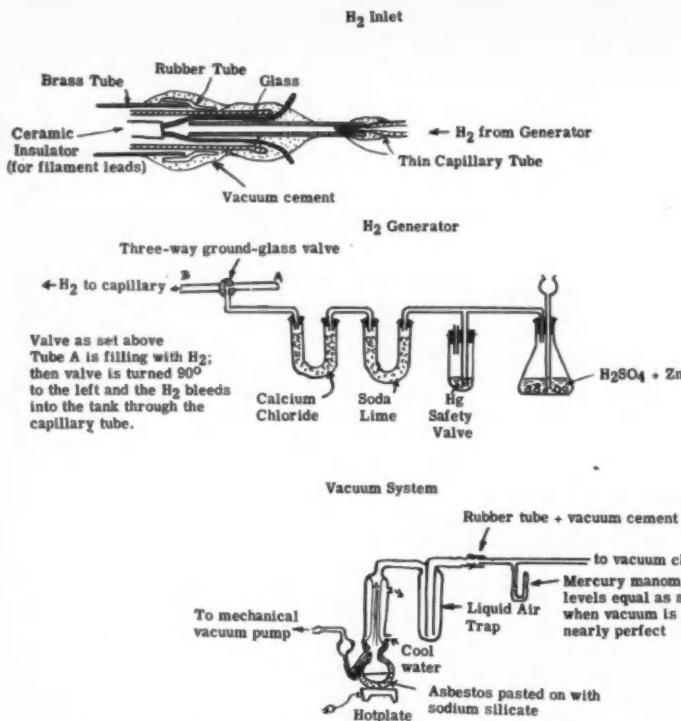
24 counter sunk machine screws. These screws fit into tapped holes in the bottom plate. There are four inlets into the chamber:

1. The lead to the dee. (It should be pointed out that the chamber proper is the other dee.)
2. The lead for the filament and for the hydrogen admission.
3. The target probe.
4. The tube for the evacuation of the chamber.

The dee itself is constructed of copper and is soldered together. The lead to the dee is a  $\frac{1}{4}$  inch copper pipe passing through a seal coated with vacuum cement. The filament is one taken from an automobile headlamp and draws about three amperes when glowing red hot. However, because of a high rate of breakage experienced, I plan to replace it with an arc ion source. The hydrogen is admitted to

the vacuum chamber through a three way ground glass valve where it is ionized by the electrons given off by the filament. The target is a small quantity of lithium nitrate fused to a steel block threaded on the end of the target probe. I used this method to eliminate the necessity of having a deflecting plate and the other complications necessary for an outside target. The beam current will be detected by a microampere meter. A Geiger counter will be used to detect any radiation emanating from the vacuum chamber during operation and to detect the induced radioactivity of the target later.

The evacuation of the chamber is first effected by an ordinary mechanical vacuum pump which will take the vacuum down to five millimeters. From there on a mercury-vapor pump takes over. This should be used with



a liquid air trap, but as yet I have not used this arrangement. However, without this I have had the vacuum down to less than one millimeter. This reading is probably very general, since it was taken from a mercury manometer in which the mercury levels were even to the naked eye. Later I plan to use a McLeod vacuum gauge for very accurate readings.

I have recently completed the construction of all these units, and at present I am attempting to correlate

them so that a proton beam will be formed. I have made several test runs already, but for various reasons such as the filament's burning out or the vacuum system's springing a leak, I have not obtained a beam. However, I shall continue trying, and in the near future I hope to obtain a proton beam of  $\frac{1}{2}$  Mev or more. Once this has been done I shall expose fruit flies and other laboratory animals to the gamma rays or radioactive isotopes produced and continue my research.

## Appendix

### Calculations Used

$$E = \frac{q^2 (Hr)^2}{2m}$$

where:

H = magnetic field in oersteds  
 E = kinetic energy of ion in ergs  
 q = charge of ion in e mu  
 m = mass of ion  
 r = radius in cm.

$$.8 \times 10^{-6} = \frac{(1.6 \times 10^{-20})^2 (7 H)^2}{2(1.6729 \times 10^{-24})}$$

$$\begin{aligned} & 2.54 \\ & \times 3 \\ & \hline 7.62 \text{ cm. or } 7 \text{ cm.} \end{aligned}$$

$$.8 \times 10^{-6} = \frac{2.56 \times 10^{-40} \times 49 H^2}{3.3458 \times 10^{-24}}$$

$$1/2 Mev = .8 \times 10^{-6} \text{ ergs}$$

$$.8 \times 10^{-6} = \frac{125.44 H^2}{3.3458} \times \frac{10^{-40}}{10^{-24}}$$

$$F = \frac{Hq}{2\pi m}$$

$$.8 \times 10^{-6} = 37.44 H^2 \times 10^{-16}$$

$$F = \frac{14,600 \times 1.6 \times 10^{-20}}{6.28 \times 1.6729 \times 10^{-24}}$$

$$.8 \times 10^{10} = 37.44 H^2$$

$$F = \frac{23,360}{10.5} \times \frac{10^{-20}}{10^{-24}}$$

$$.0214 \times 10^{10} = H^2$$

$$F = 2225 \times 10^4$$

$$\sqrt{.0214 \times 10^{10}} = H$$

$$F = 22,250,000 \text{ cycles/sec.}$$

$$14,600 = H \text{ oersteds}$$

$$\text{or } 22 \text{ mc.}$$

In this case oersteds = gausses. One gauss equals one line per square centimeter.

Since the B-H curve (graph) of the iron is in terms of lines per square inch and ampere-turns, I must convert the gaussess to lines per square inch.

$$\frac{\text{lines / sq. in.}}{\text{sq. in. (in cm)}} = \frac{\text{lines / sq. cm.}}{\text{sq. cm.}}$$

$$\frac{x}{(2.54)^2} = \frac{15,000}{1}$$

$$x = 15,000 \times 6.45$$

$$x = 97,000 \text{ lines / sq. in.}$$

Using a normal magnetization curve for annealed sheet steel (USS Electrical), 54 ampere-turns per inch are needed to produce a flux density of 97,000 lines per square inch. The magnetic circuit is 55½ inches long; therefore I shall need 55½ x 54 or 2,997 ampere-turns, assuming the circuit has no air gap. However to force 97,000 lines per square inch through 1¼ inches of air, 37,750 ampere-turns are needed thus making a total of 40,747 ampere-turns needed. Using a coil of 5,000 turns I would

have to run  $\frac{40,747}{5,000}$  or 8.1 amperes through the coils.

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I should here like to express my gratitude for materials obtained from the following companies:

Niagara Mohawk Power Corporation

Westinghouse Electric Corporation  
Linde Air Products Corporation

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## On Back Cover

► HOME-MADE CYCLOTRON shown by its builder, Robert Edmund Simpson, of Kenmore High School, Kenmore, N. Y. Robert made the building of the cyclotron his science project for entry in the Tenth Annual Science Talent Search. In the photograph he is demonstrating how his oscillator will light the fluorescent tube he holds

in his hand. More than three thousand pieces went into the assembly of the magnetic coil in the center of the apparatus. Robert obtained expert criticism from Dr. E. O. Lawrence on his plans for the half-million electron volt machine before he built his atom smasher.

## Cosmic Ray Origin

► IT IS AS YET AN UNSOLVED MYSTERY whether cosmic rays which continually bombard the earth from somewhere in outer space, smashing into our atmosphere, receive their tremendous energy within our planetary system or in the region of the Milky Way or whether they originate in between the many galaxies which fill the universe.

One result which may bring us closer to unravelling the mystery was recently reported by the late Dr. H. L. Bradt and Dr. B. Peters of the University of Rochester. They measured the abundance of lithium and other light elements in the primary radiation and concluded that on their

## Unsolved Mystery

voyage through space the cosmic rays do not traverse large amounts of interstellar matter and suffer few collisions with the gas atoms in the very rare atmosphere between stars.

However, these primary cosmic rays collide with atoms in the atmosphere to form many different kinds of particles, protons, mesons and neutrons. The energies of these secondary cosmic rays are many times greater than those available in man-made accelerators.

By studying these mysterious rays and the atomic havoc they cause, scientist expect to learn much about how and why the atom is held together.

Science Talent Search  
Essay and Project, 1951

## Beta Radiation Count Rate

by ROBERT ALAN SPANGLER  
*Celina High School, Celina, Ohio*

► RADIOACTIVITY, brought to the focal point of public attention by the recent spectacular utilization of atomic energy, has developed under the influence of concentrated war-time research into a wide field of modern physics, and includes many phases.

By means of this series of experiments, I am attempting to demonstrate by statistical evidence several principles of nuclear research.

The specific experiments are:

- (1) determining the beta absorption curve of aluminum;
- (2) determining the effects of the geometry of the source on the count rate, and comparing the theoretical and actual radiation intensities for various placements of the source.

### Materials and Apparatus

For measurement of radiation intensity, I used a Victoreen Counter Tube (Victoreen Instrument Company, Cleveland, Ohio) type 1B85, together with associated amplifier and indicating devices. The tube, filled with a self-quenching gas, has  $30\text{mg./cm.}^2$  aluminum walls, and was mounted in a rectangular lead shield with walls 2 cm. thick. See Appendix I for details of measurement equipment.

The material for the activity source was separated from a uranium ore,

carnotite, by the chemical process listed in Appendix II. A source of comparatively low activity (174 cpm.) was used in the experiments in order to reduce the probability of error because of dead time in the tube, and lag in the mechanical counter.

Aluminum foil,  $4.8\text{ mg./cm.}^2$ , was used for the absorption screens.

### Background Count

Before beginning the actual experimental measurements, it was necessary to determine the background count. An average of two one-hour counts, made on separate evenings, was 38.59 cpm., the difference between the two readings being .66 cpm.

The average background count was subtracted from each measurement to indicate the true activity count.

After several hours of tests, the background increased to 42 cpm. This was probably because of the adsorption of active materials by the shield. It became necessary to determine the background before each series of measurements.

### Aluminum Absorption Curve

The purpose of this experiment is to demonstrate graphically the absorption characteristics of aluminum screens of various mass/area. From a graph of this type the energy level and composition of the measured radiation can be determined.



► BETA-RAY counter is exhibited by Robert Alan Spangler of the Celina, Ohio High School, at the Science Talent Search reception in Washington. He holds a sample of radioactive material in front of the counter he made.



► GRAPH I. a and b.—Graphs of Count Rates, left, and Logs of Count Rates, right, as determined by Spangler's Beta Radiation Counter, plotted against Mass/Unit Area Ratio.

### Procedure

The radiation source was placed in the shield and left in the same position for all measurements of this experiment. The aluminum screen, composed of a specific number of layers of the foil, was placed in position, and the indicated number on the mechanical counter noted. Before starting the count, the amplifier and high voltage supply were allowed to warm up enough to become stabilized.

After the count was taken for a definite time period, the indicated number was again noted. From this reading was subtracted the original number, and the remainder divided by the time. The background was subtracted, and the final count placed in the appropriate position on the graph.

Because of the low activity of the source, counting periods of at least 20 minutes were necessary.

### Results

The results of this experiment are indicated in Graph I. Both the counting rate and its log are plotted against the mass/area in the graph.

### Discussion and Conclusions

Several factors — variations in the background, possible non-uniformity of foil thickness, diffusion of the beta particles, and counter lag—tended to

decrease the accuracy of the measurements. In spite of these factors, the readings fell along a well-defined curve in the graph, thus verifying the probability of fair accuracy.

The logarithmic curve of the count rate is composed of several straight line segments. This would indicate the total activity is composed of several continuous beta ray spectra with different maximum energy levels.

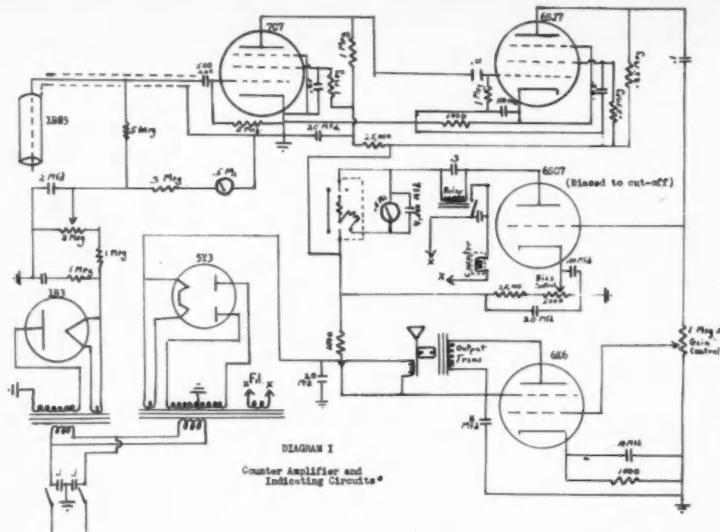
It is doubtful that the last slope shown on the graph can be attributed to gamma radiation. For a gamma photon to have a half-thickness value shown in the graph, it would have an energy of about 10 ev. (Extrapolating Photon-absorption Coefficient table to indicated absorption coefficient)

Because of the extremely low photon detection efficiency of the counter, the gamma radiation cannot be accurately indicated by this apparatus. However, the electrons ejected from the aluminum by the passage of gamma rays lowers the accuracy of the beta count.

### Effects of Geometry

By this experiment I am comparing the actual and computed theoretical count rates of the same sample in various geometric placements.

Careful measurement of the di-



mensions of the shield, the counting tube, the source diameter, and their relative positions was made with the source in two positions. From this data the theoretical ratio of the count rates was computed. The actual count ratio was found by measurement with the source in the two positions, and the two ratios were compared.

With the source in a position 7.8 cm. from the tube, the computed geometry was .6915%, while the source, when 5.8 cm. from the tube, had a computed geometry of 1.4662%. The count rate ratio from these two values is 2.1158 to 1.

The measurements of the source in the two positions were 49.88 cpm. at a distance of 7.8 cm., and 106.35 cpm. at 5.8 cm. The count ratio from the two measurements is 2.132 to 1. Assuming that the computed ratio is the

correct value, then there is an error of .766%.

The mathematical process for computing the geometry is illustrated in Appendix III.

### Discussion and Conclusions

The results of this experiment were very satisfactory. Not only do the results prove the great effect of geometry on the count rate, but the experimental data agree with the theoretical values to within 1%.

However, because of uncontrollable factors which affect the count, such as unequal propagation and diffusion of the radiation, it is very seldom that the results agree so closely, and in this case luck probably had a large role.

The results of these experiments will never go down in history as an outstanding contribution to science, but in a mushrooming field, as nu-

clear physics is, every tiny bit of knowledge aids the cause.

*Appendix I*—The Victoreen counter tube used for these experiments has an active length of 7 cm., a diameter of 2 cm., is filled with a self-quenching gas, and has a plateau length of 200 volts with 3%/100 volts slope.

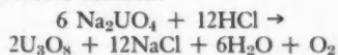
The output of the counter is coupled into a high-gain amplifier, and the amplified pulse actuates a speaker, meter, and mechanical counting device. The mechanical counter, used for all measurements, is the 0.99,999 non-resetting type made by the Mercury Production Instruments Co., and is powered by the 6 volt 60 cycle AC filament supply.

See the schematic diagram of the amplifier and indicating circuits for complete details.

The counter tube was mounted in a rectangular lead shield with walls 2 cm. thick. The inner dimensions of the shield are 10 cm. x 10 cm. x 4.8 cm.

*Appendix II*—For a source of activity, I preferred to prepare my own from crude ore rather than purchase a commercial product.

Four ounces of carnotite supplied sufficient active material for my experiments. The uranium was separated from the other constituents of the carnotite by a process suggested by the Encyclopedia Britannica, with sodium uranate ( $\text{Na}_2\text{UO}_4$ ) as the final product. This was reduced to  $\text{U}_3\text{O}_8$  by reacting it with hydrochloric acid. The probable reaction:



*Appendix III*—The computation of geometry of the source in various positions was complicated by the lead

shield form. The shield is box-like with the counter mounted at the top above a lead shelf. The source is placed below the shelf. See diagram II.

In the shelf is a circular hole, 2.88 cm. in diameter. Assuming that the radiation from the source, mounted on the axis of the hole, travels in straight paths, then there will be above the aperture projected on the plane of the counter tube a circular area of maximum radiation intensity, subtending  $\theta/a$  at the source.

Surrounding this area, and concentric with it will be a ring of decreasing intensity caused by the partial shadowing of the source by the hole. This ring subtends  $\theta/b$  at the source.

Let the radii of the two areas be  $r_a$  and  $r_b$ , respectively, and the distance from the source to tube d.

Plotting the circle and ring against the intensity, in a three dimensional graph, the resulting figure is a frustum of a cone, with an altitude proportional to the maximum intensity ( $I_1$ ), and the volume proportional to the total energy intercepted ( $E$ ).

The total energy intercept can be expressed:

$$E = \frac{I_1 \pi (r_a^2 + r_a r_b + r_b^2)}{3}$$

But it is necessary to determine the average intensity ( $I_b$ ) of the partially shaded area, obtained by subtracting from the total energy intercept ( $E$ ) the total energy intercept of the unshaded area ( $E_a$ ), and dividing the remainder by the area of the shaded ring ( $A_b$ ).

$$E_a = I \pi r_a^2$$

$$A_b = \pi (r_b^2 - r_a^2)$$

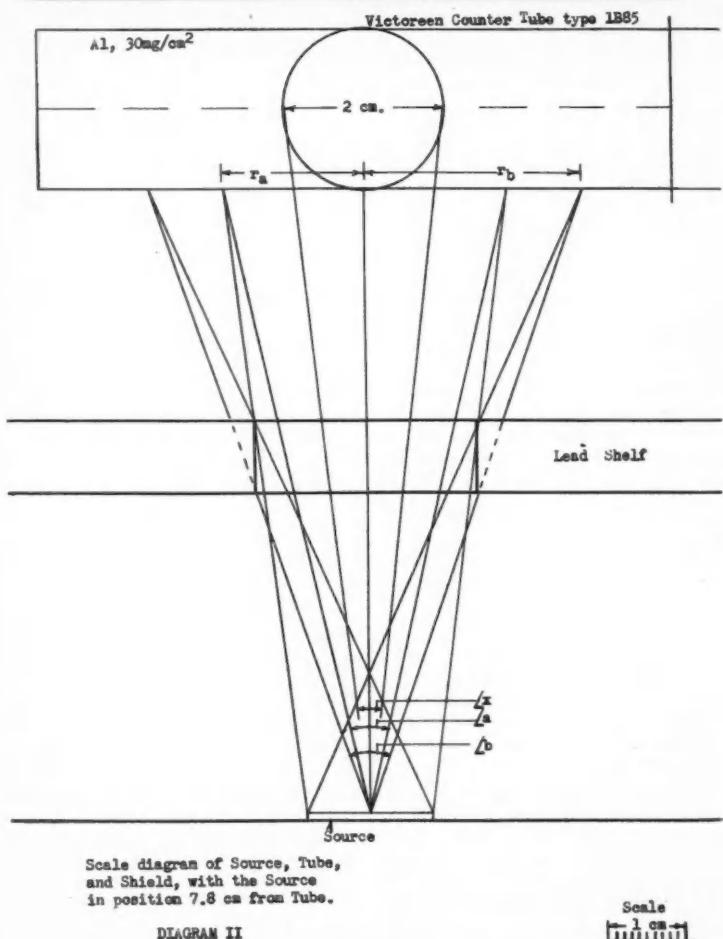


DIAGRAM II

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Combining equations 1, 2, and 3:

$$I = \frac{I (2r_a + r_b)}{3(r_a + r_b)}$$

Assuming that the beta particles are emitted from the source equally in all directions, it follows that the ratio of the radiation intercepted by the tube to the total radiation will be the same as the ratio of the angular area occupied by the tube to the total angular area of a sphere.

That is:

$$\frac{E}{E_{\text{total}}} = \frac{\angle_b \cdot x}{360 \cdot 180}, \text{ where } \angle_x$$

is the angle subtended at the source by the diameter of the counter tube.

The angular width of the tube decreases from the center of the tube to the circumference of the ring because

$$\frac{E}{E_{\text{total}}} = \frac{(\angle_b - \angle_a) \cdot \angle_x \cdot x + \angle_a \cdot \angle_x}{360 \cdot 180}$$

## New Automobile Windshield Glass

►MOTORISTS will benefit by a new automobile windshield glass that reduces road glare and heat. It is a glass of excellent optical qualities which is tinted a slight bluish-green in color and has a graduated shading above the eye level.

This tinted safety plate glass is a product of Libbey-Owens-Ford Glass Company and has already been thoroughly road tested in many parts of the United States. It passes the light-transmission requirements of the American Standards Association with a good margin to spare, according to

of the increased distance from the source. The average angular width must be determined for each area, both the shaded and unshaded areas.

Because of the decreased effective energy interception per unit area in the shaded ring, the geometry of this area must be computed separately from the unshaded circle.

The ratio of the maximum intensity to the effective intensity of the shaded area ( $X$ ) can be found by removing  $I$  from the right side of equation 4:

$$\frac{I_h}{I} = X = \frac{2r_a + r_b}{3(r_a + r_b)}$$

This factor must be included to find the effective geometry of the shaded ring. The final equation for determining the geometry:

$$\frac{E}{E_{\text{total}}} = \frac{(\angle_b - \angle_a) \cdot \angle_x \cdot x + \angle_a \cdot \angle_x}{360 \cdot 180}$$

G. P. MacNichol, Jr., of the glass company. Its use will make outside sun visors unnecessary.

The bluish-green tint in the glass itself is obtained by mixing iron oxides in the glass during manufacture. By balancing the ingredients properly, it was found possible to eliminate about one-third of the sun's glare-producing rays and one-half the heat rays and still preserve the optical qualities of the glass. A secret process is used to produce the modulated shading of the plastic in the upper part of the windshield.

**Science Talent Search  
Essay and Project, 1951**

## **Construction of a Wilson Cloud Chamber**

*by NICHOLAS ALLAN WHEELER  
The Dalles High School, The Dalles, Oregon*

► FOR THE PAST three years I have been working in my spare time designing and constructing a Wilson cloud chamber. Before a practical plan was developed, many designs were considered. The cloud chamber described here is the second on which construction was actually begun, a previous model having been found unsound in principle before it was completed.

The working part of this cloud chamber consists, essentially, of a brass cylinder 6" in diameter, with a thin rubber diaphragm covering the bottom and Plexiglas windows in the top and sides.

Before each expansion is made, water vapor is forced into the upper chamber by means of an atomizer system, until the air in this space becomes saturated. When this condition is reached a specially-designed electro-mechanical synchronizing unit (see Fig 6) energizes a powerful electric solenoid. This solenoid quickly opens a large-capacity air valve (see Fig. 2), allowing part of the air beneath the rubber diaphragm to rush into a partially evacuated three-liter flask. This outrush of air causes the diaphragm to be sucked down, simultaneously and almost instantaneously expanding, cooling, and super-

saturating the air in that part of the chamber above the diaphragm. Droplets of the super-saturated vapor immediately condense on the ion paths formed by the passage of sub-atomic particles emitted from a radio-active source, (supposedly) causing clouds, or tracks. (The ions normally present in the air are removed by applying an electrostatic potential to a pair of grids in the chamber). These tracks are illuminated through the windows in the sides of the chamber and viewed from the top. The inside of the chamber is blackened to aid in making the clouds visible. At the instant of their formation, the tracks (when I succeed in producing them) are photographed by a camera operated by the synchronizing unit. When the time which this whole process takes has elapsed (considerably less than one second) this unit closes the main air valve, partially preparing the chamber for another expansion.

### **Features of the Design**

The apparatus was designed so as many factors would be variable as possible, thereby permitting greater experimental range. This necessitated including certain elements, e.g., the synchronizer, which are not usually found in small cloud chambers, and presented a number of problems. Suc-

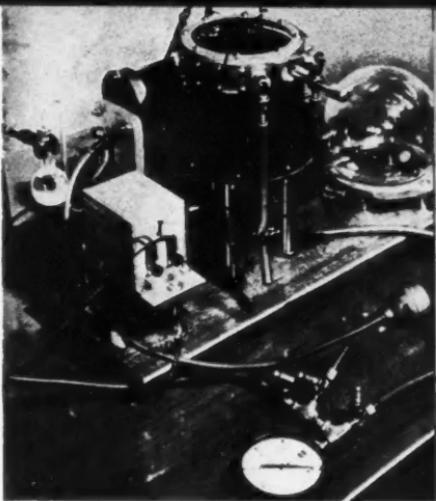
cess was finally attained, however, in making changeable the radio-active source, the types of gas and vapor used, the grid voltage, and the initial and expanded volumes and pressure. It is also possible to insert lead plates and other shielding materials. Terminals to introduce auxiliary voltages into the chamber are included. The most noteworthy parts of the design include the diaphragm mount, the main air valve, the synchronizing unit, and the atomizer system.

### Preliminary Adjustments

Since construction was completed only recently, I have not yet had sufficient time to remove all the defects from the apparatus. While I have not yet succeeded in producing tracks, I have, by altering the vapor system and experimenting with different expansion ratios, been able to produce the dense fog which, I have read, occurs when the expansion is over 38%. It is in the expansion ratio range of 1.25-1.38, the "region of rains," in which tracks of sub-atomic particles should be observed. At present I am engaged in reducing the grid voltage and expansion ratio, intensifying the light source and designing a more effective air filter, all in the hope that the tracks will become a reality. To accomplish this, of course, all parts of the design and operational processes as described here are subject to change.

### Cloud Chamber

Detailed descriptions of the parts of the Cloud Chamber follow, including the devices Wheeler has put together to control the various factors affecting the operation of his apparatus.—Editor's note.



► THE CLOUD CHAMBER is Fig. 1 in Wheeler's description of how he built his apparatus.

### KEY TO FIGURE 1

- A. Atomizer bulb
- B. Water or solution to be vaporized
- C. Atomizer
- D. Baffle
- E. Ion eliminator grids
- F. Radio-active source chamber
- G. Air inlet and outlet (to upper chamber)
- H. Main valve
- I. Valve solenoid
- J. Vacuum flask
- K. One of three rods used to raise and lower the diaphragm mount
- L. Vacuum adjustment and control assembly
- Not shown are the air filter, camera, and light source

### The Solenoid. Fig. 2

When the solenoid is energized, it pulls the plunger (A) to the left; first closing the air inlet (B) and then opening the entrance into the partially evacuated flask (C). When the timer (Fig. 6) turns off the solenoid, the difference in air pressure causes the plunger to return to its original position, thereby closing off the flask and allowing air to return into that part of the chamber beneath the diaphragm through the air inlet.

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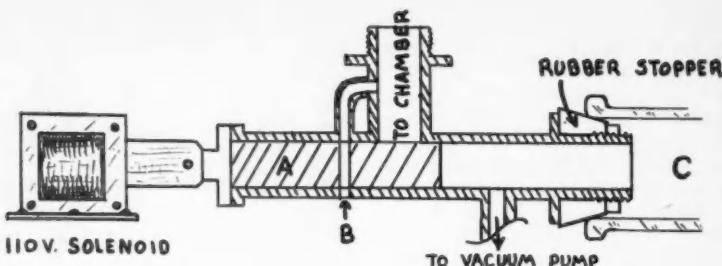


Fig. 2

**The Vaporizer, Fig. 4**

When the rubber bulb (A) is compressed, air is forced through the filter (B) and on through an atomizer (C). The solution to be vaporized is contained in a flask (D), from which it is fed by a siphon to the atomizer. The use of a siphon was found necessary because the rubber bulb does not produce an air velocity high enough to raise a solution more than a short distance (Bernouilli's principle). As the spray and vapor leave the atomizer they pass into a baffle (E), from which only the smallest droplets

APPROX. SCALE:  $\frac{1}{8}$ " = 1"

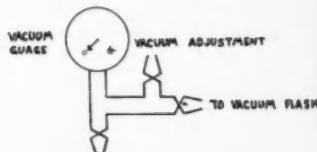


Fig. 3 TO VACUUM PUMP

pass into the cloud chamber. The test tube (F) was inserted here because droplets tended to form on the walls of the tube leading from the baffle into the chamber. These droplets now collect in the test tube.

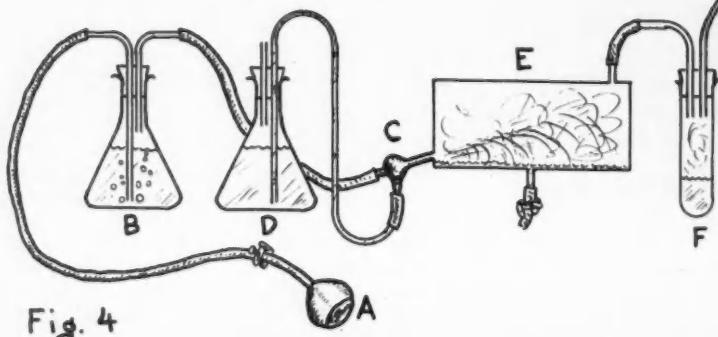
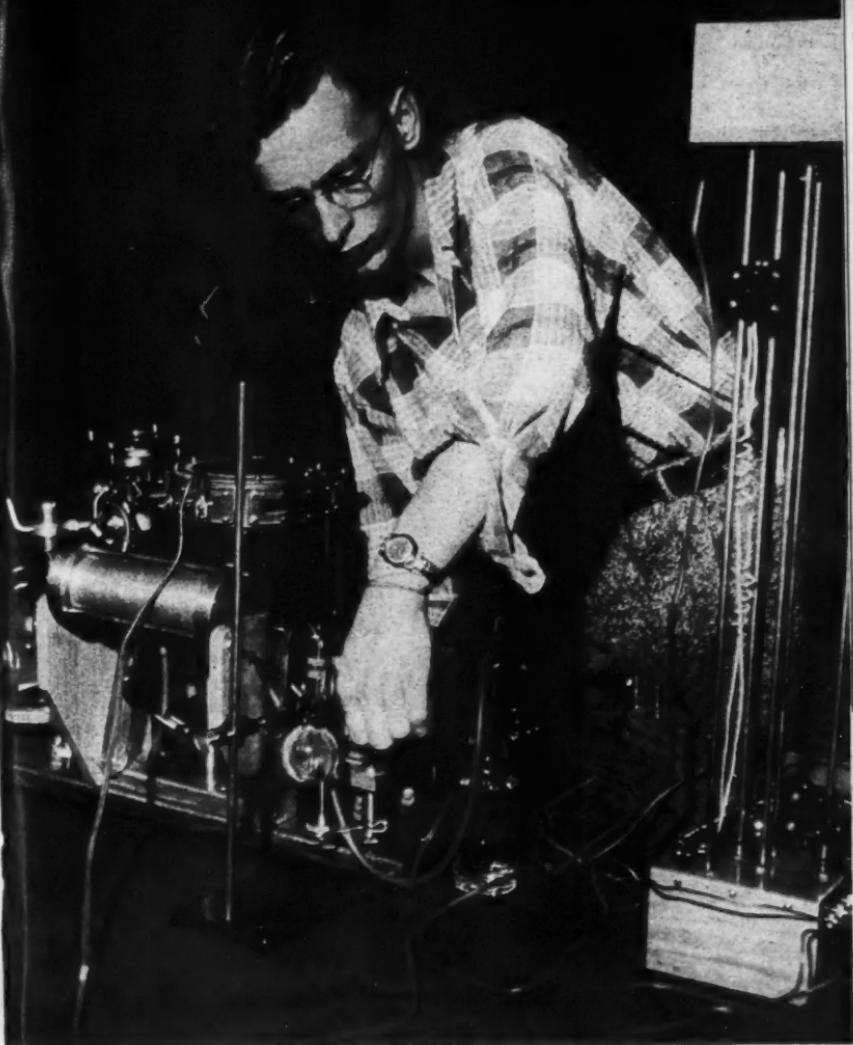


Fig. 4



►CLOUD CHAMBER apparatus which he constructed is shown by Nicholas Allan Wheeler, of The Dalles, Oregon, High School, during the Tenth Annual Science Talent Search.

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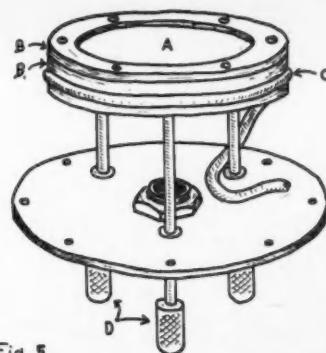


Fig. 5

### The Diaphragm. Fig. 5

A rubber diaphragm (A) is held tightly between two wooden rings (B and B), the outside diameter of which are just less than the inside of the brass cylinder which forms the walls of the cloud chamber. Encircling one of these rings is a groove in which is placed a rubber tube (C) which passes out through the side of the chamber. When the air is removed from the tube it collapses, decreasing the overall diameter of the ring and thus allowing the diaphragm to be raised or lowered by means of rods (D) which extend through the bottom plate of the chamber. This increases or decreases the initial volume of the cloud chamber proper.

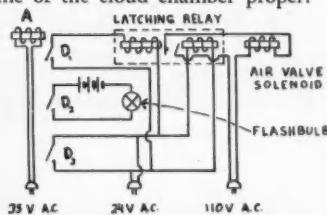
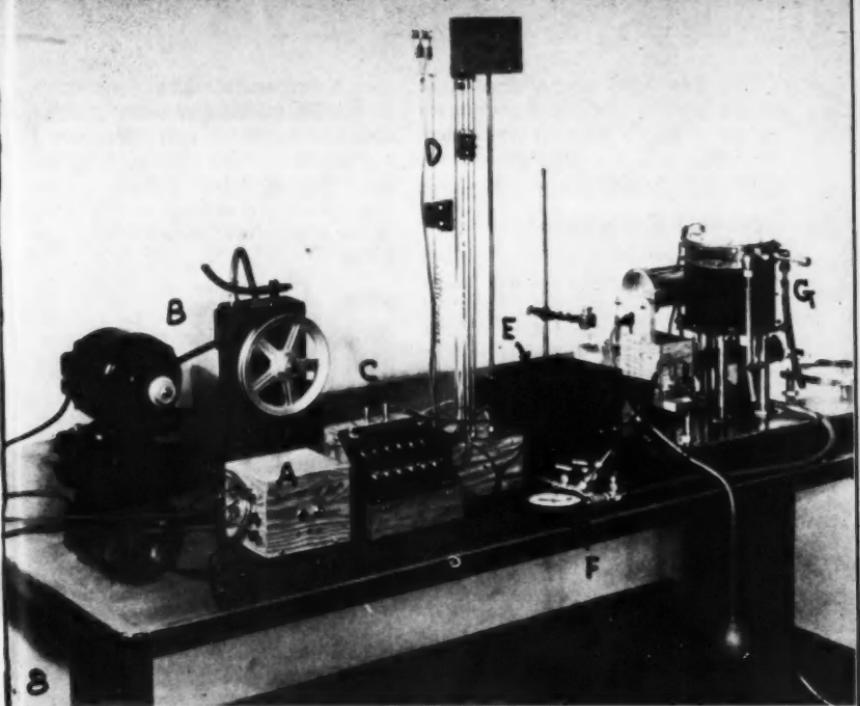


Fig. 7



► FIG. 8, showing Wheeler's complete set-up. The parts are: A. Transformer, producing 35 and 25 volts; B. Vacuum pump; C. Master control panel; D. Synchronizing unit; E. Full wave rectifier (well-filtered); F. Vacuum adjustment gauge and valves; and G. Main unit.

### The Synchronizing Unit, Fig. 6

The need for a synchronizer arises from the fact that the action of the solenoid, movement of the air, and response of the diaphragm are not instantaneous processes, a definite time interval existing between the closing of the solenoid switch and the formation of the fog or tracks. This interval must be compensated for when photographing the tracks.

When a switch on the main control panel is closed, the 35-volt solenoid (at A in Figs. 6 and 7) trips a lever

(B) allowing a  $\frac{7}{8}$ " ball-bearing (C) to fall, tripping a series of microswitches ( $D_1$ ,  $D_2$ , and  $D_3$ ). The first microswitch ( $D_1$ ) closes a latching relay, thereby energizing the main air valve solenoid. As the ball continues downward it closes the next switch ( $D_2$ ), igniting the flashbulb which illuminates the interior of the chamber, exposing the plate. As the weight comes to rest it snaps a third switch ( $D_3$ ) which again opens the relay, allowing the air valve to close.

The time intervals involved may be changed by moving the switches up and down the rods on which they are supported. The greatest interval possible is about  $\frac{1}{3}$  of a second.

### Proposed Experiments

More important than the construction and design are the experiments which I hope to perform. When we are able to produce tracks of the proper quality, the following experiments are in order:

a. A study of the effectiveness of lead plates and other shielding materials.

b. A study of the respective penetrating powers of alpha, beta, and gamma radiation.

c. The mathematical analysis of nuclear collisions and transformations. (At present, however, I have not enough mathematics to accomplish this.)

d. A study of reactions involving neutrons.

e. A study of the effects of a magnetic field of known intensity on alpha and beta particles, from which could be calculated their respective masses and velocities. (The chamber is constructed entirely of brass in order that this magnetic field would not be distorted).

f. An investigation to determine the effect of a high-amperage current through a metal plate on sub-atomic particles passing perpendicularly through that plate.

g. An investigation into the possibility of using an ultra-sonic beam to super-saturate the air in a cloud chamber. (Perhaps this would lead to the development of a continuous cloud chamber).

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## Corrosion Measured by New Method

► CORROSION, including rusting, is being measured as it takes place at the Illinois Institute of Technology by a method that picks up the minute electrical currents created by the chemical reaction, enabling scientists to measure and study the process.

Corrosion, of which rusting is an example, is caused by thousands of local cells similar to microscopic flashlight batteries. The electrochemical cells are formed by corrosive chemicals and the metal itself, Dr. Howard T. Francis of the Institute's staff explains.

In the process, a metal cylinder is used as the laboratory sample on which corrosion occurs. This cylinder is dipped in some corrosive solution, such as sea water, rotated several hundred times a minute, and scanned with a stationary probe electrode.

The probe is a plastic arm containing 11 silver wires. In use it is placed very close to, but not touching, the submerged cylinder. It picks up the minute electrical currents caused by corrosion and carries them through an amplifier to observation and measuring devices.

**Science Talent Search  
Essay and Project, 1951**

## A New Set of Organic Compounds

by LENNARD WHARTON  
*Phillips Exeter Academy, Exeter, N. H.*

► ORIGINAL RESEARCH in any field of science is an interesting and stimulating study. It is the basis of science and the scientific method, for the experiments of original research provide the data upon which the laws of science are founded. Scientists throughout the ages have collected the data of original research experiments and from them have tried to create general laws or theories which not only explain what has happened, but also what will happen. The ordering and cataloging of the laws of nature as discovered through original research experimentation is indeed the progress of pure science. It is therefore up to the original researcher to record his data accurately and truthfully and to notice carefully all phenomena concerning the object of his research, for the more watchful and observant the researcher, the more complete and correct will be his theory or law.

But original research is something more than just the mechanical collection of data. It is not only a science; it is an art. Accurate and complete results are the masterpieces of a good laboratory artist. There is also present a piquant feeling in the researcher's heart for the work that he is doing. He is doing something constructive; something for science, progress, and man. He has the satisfaction of having done something that

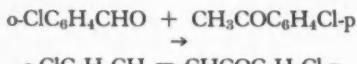
no other man has done; he has witnessed wonders never before seen by human eyes. In research there is always room for originality and imagination since there is no limit, no law which must be adhered to. The researcher has complete freedom of thought in his work. Finally he has the scholar's pride when he informs the world of new discoveries and new horizons.

### Synthesis Procedure

The substances selected for study as a Science Talent Search project were o-chlorobenzoyl-p-chlorobenzoylmethane and some of its derivatives. Past studies on o-chlorodibenzoylmethane revealed that derivatives of this compound have low melting points and are very difficult to isolate.<sup>1</sup> p-Chlorodibenzoylmethane, on the other hand, was very easy to handle as its derivatives tended to be higher melting. It was therefore decided to use o-chlorobenzoyl-p-chlorobenzoylmethane for study in the hope that the influence of a para chlorine would make derivatives of this compound have higher melting points than the similar derivatives of o-chlorodibenzoylmethane.

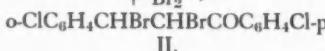
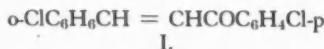
o-Chlorobenzoyl - p - chlorobenzoylmethane was prepared in the following way: o-Chlorobenzaldehyde was condensed with p-chloroacetophenone in the presence of NaOH in methyl

alcohol. The expected o-chlorobenzal-p-chloroacetophenone I. was isolated in good yield.

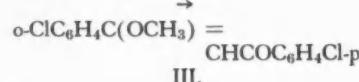


I.

The subsequent bromination of the product in chloroform gave the expected dibromide II. in good yield.

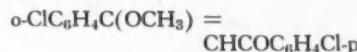


Following treatment with KOH in hot methyl alcohol, the dibromide did not give the expected stable methoxy compound III.



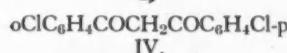
The product obtained from the treatment of the dibromide II. with KOH in methyl alcohol changed color; the white crystals taken from the mother liquor turned first orange and then pale-yellow on the surface. When placed in a dark drawer, the product regained its former white color. This plus the fact that the melting point was not sharp indicated the presence of an unstable, impure compound. Attempts to isolate the methoxy compound from it were unsuccessful. It should be noted here for the sake of comparison that  $\beta$ -methoxy-o-chlorobenzalacetophenone was isolated in good yield when it was made.<sup>2</sup> Upon

treatment with alcoholic KOH and then concentrated HCl, it did give o-chlorobenzoyl-p-chlorobenzoylmethane IV, the product expected if the methoxy compound were treated in the same way.



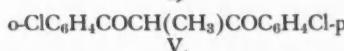
III.

$\rightarrow$



It was therefore concluded that the methoxy compound had been formed with another substance which caused the color change and the wide melting point range. The dibromide II. was also converted to the diketone by treatment with KOH in alcohol and subsequent treatment with HCl. In both cases mere crystallization of the product was not sufficient to purify the diketone. It was necessary to precipitate the copper salt of the diketone enol and then to treat the insoluble copper salt with acid to reconvert it to the diketone. In both cases the purification process was good as both samples were sharp-melting, but the yields of the processes used in the synthesis were very poor.

An attempt to make the methylated diketone V. by treating the diketone with methyl iodide and silver oxide in anhydrous ether<sup>3</sup> proved unsuccessful.



A solid product was obtained in poor yield which emitted the odor of o-chlorobenzaldehyde. It is believed that the compound decomposes slowly



► NEW ORGANIC compounds are the project of Lennard Wharton who showed samples of the materials and diagrams of their structure at the Tenth Annual Science Talent Search.

since it still smells six months after being made, and its melting point, which is 45° to 65° C., indicates that the product is impure. However, no reasonable explanation for the cleavage of the product to yield o-chlorobenzaldehyde has as yet been discovered. Formerly it was believed that a too low melting point was the reason for the failure to synthesize 1-(o-chlorobenzoyl)-1-benzoylethane. But since this experiment shows that an unstable product is obtained in attempting the methylation of a similar o-chloro diketone, it is now concluded that the

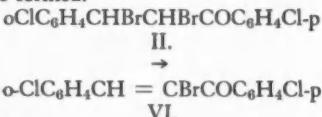
presence of the ortho chlorine may hinder the methylation of any o-chlorodibenzoylmethane derivative.

It was also attempted to make the enol of the methylated diketone by treating the methylated diketone with base and then pouring the product into iced HCl. A solid product came out, but as yet no tests have been made with it.

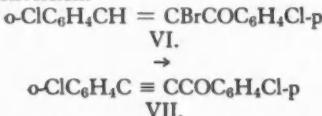
#### Possible Further Study

There is still much experimentation which can be carried out in the study of the derivatives of o-chlorobenzoyl-

p-chlorobenzoylmethane. If the dibromide II. is treated with KAc in methyl alcohol, the monobromide VI. should be formed.



This in turn may be able to be converted to the highly unsaturated and reactive acetylenic ketone VII. which can be treated to give products worthy of study. KOH in acetone effects the conversion.



The diketone IV. may be prepared from the acetylenic ketone VII. by hydrolysis with  $\text{H}_2\text{SO}_4$ . Perhaps this method would give a better yield of

the diketone than the method used. Likewise the methoxy compound may be made from it since  $\beta$ -methoxybenzalacetophenones have been made from their acetylenic ketones in many cases by treatment with KOH in methyl alcohol.

A careful study of the decomposition of the methylated diketone should be made since no other compound made has decomposed in such a manner and since no reasonable explanation for the cleavage of the substance to yield o-chlorobenzaldehyde has been discovered. Experiments with scale spatial molecule models have not indicated any bonding strains within the molecule.

## REFERENCES

- <sup>1</sup> Bickel, Journal of the American Chemical Society, 68, 885 (1946).
- <sup>2</sup> Bickel, Journal of the American Chemical Society, 68, 885 (1946).
- <sup>3</sup> Bickel, Journal of the American Chemical Society, 67, 2045 (1945).

## Experimental

### *A. The preparation of o-chlorobenzal-p-chloroacetophenone*

To 150 grams of p-chloroacetophenone, 150 grams of o-chlorobenzaldehyde, and 400 ml. methyl alcohol in an ice bath, a solution of 30 grams of NaOH in 200 ml. methyl alcohol was added with stirring. Stirring was continued for 60 minutes. The color of the mixture deepened at first to an orange-red; three minutes later it lightened to yellow. A solid separated. During the last thirty minutes of the stirring, 400 ml. water was run in. The whole mixture was then put in the refrigerator overnight. The solid was filtered out, washed with 400 ml. cold 50% methyl alcohol, and washed with water until free of base.

The product was air dried. It recrystallized from ether as pale yellow plates which melted at 84° C. The 263 gram yield based on the amount of p-chloroacetophenone used was 98%. Quantitative analysis of the product gave the following results: Calculated: C: 65.0 H: 3.6 ; Found C: 65.2 H: 3.7

### *B. The preparation of o-chlorobenzal-p-chloroacetophenone dibromide*

152 grams of bromine were added to a cooled solution of 263 grams of the benzalacetophenone in 1000 ml. chloroform. Some HBr appeared toward the end of the process. The solution of the product was evaporated with a current of air giving a solid product. It recrystallized from ether

as long plates which melted at 113° C. The 403 gram yield was 97%. Quantitative analysis of the product gave the following results: Calculated: C: 41.2 H: 2.3 ; Found: C: 41.5 H: 2.5

*C. The attempt to make  $\beta$ -methoxy-o-chlorobenzal-p-chloroacetophenone*

105 grams of the dibromide were suspended in 200 ml. methyl alcohol in a one liter balloon flask. To this 35 grams of KOH dissolved in 150 ml. methyl alcohol was added. The mixture was refluxed for one hour, at the end of which time 350 ml. water was added with swirling to help the oil to come out and to help dissolve the KBr. The mixture was put in the refrigerator until all the oil had settled out. The water-alcohol solution was decanted from the solid brown cake of oil and solid. Then the residue cake was taken up in about 400 ml. ether warmed over a steam bath. The ether solution was washed with water in a separatory funnel to remove all soluble impurities and then was dried over sodium sulfate. As the solution cooled and dried over the sodium sulfate, an orange-red amorphous-looking solid came out on top of the sodium sulfate. This was unexpected as it was thought that the 400 ml. ether would easily keep the product in solution, and the only reason that the ether was heated in the first place was to shorten its time required to dissolve the product. Later this substance proved to be rather insoluble in either ether or acetone. It was set aside for inspection. The dry ether solution was boiled down and put in the refrigerator until a white solid came out. It was left out on top of the working bench under a watch glass to dry

after being filtered out. A few hours later it was noticed that it was changing color: from white to pale yellow. The color change was restricted solely to its surface. There were two possibilities for the change in color: either the acid fumes of the laboratory were converting the  $\beta$ -methoxy compound to the diketone, or the sun was effecting some change on the compound. It was proven that the sun was responsible for the color change, for the product turned white again after being placed in a laboratory drawer for 24 hours; and one hour after it was removed from the drawer, a color change to yellow was detected. A melting point test proved that the product was not pure as the melting point ranged from 90° to 100° C. The amorphous-looking solid which came out before the ether solution was boiled down also underwent a color change to gray on the surface.

*D. The preparation of o-chlorobenzoyl-p-chlorobenzoylmethane*

(1) 50 grams of the methoxy mixture, including both the substance which came out before the ether solution was boiled down and the product which came out after the ether solution was boiled down, were suspended in 200 ml. methyl alcohol. 30 grams of KOH dissolved in 100 ml. methyl alcohol were added to the suspension of the dibromide. The mixture was refluxed for one hour. At the end of the hour the mixture was allowed to cool to about 40° C. Then 56 ml. concentrated HCl dissolved in 50 ml. water was added and refluxing was continued another thirty minutes. About 300 ml. water was added with swirling to dissolve soluble impurities and to make the oily

product come out of the alcohol. The mixture was cooled in a refrigerator until all the oil had settled out. The water-alcohol mixture was decanted from the oil; the oil was taken up in about 400 ml. warm ether. The ether solution was washed with water and dried with sodium sulfate. After drying the ether solution was boiled down and kept in the refrigerator until crystals came out of the solution. The crystals obtained from the liquor proved to undergo a color change similar to that of the methoxy product. It had the rather wide melting point range of 100° to 104° C. However, in this case the product was purified from any impurities which would affect the melting point and cause a color change. An ether solution of the product was shaken with a water solution of cupric acetate. The green copper salt of the desired diketone precipitated leaving all the impurities in solution. It was filtered out and washed with both ether and water. Then it was suspended in ether in a separatory funnel to which was added enough concentrated HCl to dissolve all the copper salt. The ether layer was washed with water, dried over sodium sulfate anhydride, boiled down, and put in the refrigerator to crystallize. Very pure light-aqua-colored needle crystals melting sharply at 103° C. came out of the liquor. Quantitative analysis of the product gave the following results: Calculated: C: 61.5 H: 3.4 ; Found: C: 61.7 H: 3.6

(2) 85 grams of o-chlorobenzal-p-chloroacetophenone dibromide were suspended in 200 ml. methyl alcohol. To this 30 grams of KOH in 150 ml. methyl alcohol were added. The mix-

ture was refluxed 1½ hours and then allowed to cool to about 40° C. Then 45 ml. concentrated HCl dissolved in 50 ml. water were added to the mixture and refluxing was carried out 15 minutes more. Then about 300 ml. cold water were added with swirling to dissolve soluble impurities and to help the oily product separate from the mixture. The mixture was then kept in a refrigerator until all the oil had settled out. The water-alcohol solution was decanted from the oily product, and then the product was taken up in about 400 ml. ether. The ether solution was washed with water and boiled down to about 250 ml. It was put in a half liter Erlenmeyer flask where it was shaken with a copper acetate solution until no more copper salt precipitated. The copper salt was filtered out and washed with ether and water. Then it was suspended in ether in a separatory funnel to which was added enough concentrated HCl to dissolve all the copper salt. The ether solution was washed with water to remove the acid. It was dried over sodium sulfate anhydride, boiled down, and put in the refrigerator. Pale-aqua needles came out. A mixed melting point test ascertained that the product was the diketone. Both the methoxy mixture and the dibromide gave the diketone in very poor yields.

#### E. The attempt to make *l*-(*o*-chlorobenzoyl)-*l*-(*p*-chlorobenzoyl)ethane

5 grams of the diketone dissolved in 100 ml. anhydrous ether together with 5 grams of silver oxide and 10 grams of methyl iodide were refluxed for six hours, during which time the mixture bumped quite considerably. The opalescent solution obtained was

filtered and then boiled down to about 15 ml. A small amount of petroleum ether was added and white crystals came out after the solution was cooled in the refrigerator. They smelled of o-chlorobenzaldehyde and their melting point of 45° to 65° C. proved that they were not pure. Apparently they decomposed on standing giving off o-chlorobenzaldehyde as a product, for they still smelled six months after being made. They turned yellow from impurities formed at the surface.

*F. The attempt to make the enol of l-(o-chlorobenzoyl)-l-(p-chlorobenzoyl)ethane*

5 grams of oil which contained l-(o-chlorobenzoyl)-l-(p-chlorobenzoyl)ethane which had not been crystal-

lized from it dissolved in 50 ml. methyl alcohol and 7 grams of KOH dissolved in 50 ml. methyl alcohol were mixed with stirring. The mixture was allowed to stand for about 15 seconds before it was poured into an excess of HCl. The solution was extracted with ether. The ether solution was washed free of acid, shaken with a copper acetate solution, and the green copper salt which precipitated was filtered out and washed with water and ether. It was then suspended in ether in a separatory funnel to which was added enough concentrated HCl to dissolve all the copper salt. The ether layer was washed, dried, boiled down, and put in the refrigerator. It yielded a white solid.

## *Mildew Proofing to be Tested*

► NEW COTTON FABRICS that will stand up in desert or jungle to mildew and rot are the goal of tests by the Army Quartermaster Corps and U. S. Department of Agriculture around the world.

Anti-mildew cloth is badly needed by the armed forces for tents and uniforms that will not fall apart after a short stay in hot, tropical regions.

To test various new anti-mildew chemicals, at least four exposure stations will be set up in widely separated parts of the world. Experiments will be carried out over the next several years at these stations.

One will be in New Orleans. There, test fabrics will be treated with various fungicides by scientists at the Agriculture Department's Southern

Regional Research Laboratory, and part of the cloth will be exposed to the humid, subtropical Louisiana weather.

A hot-and-dry test station will be established by the Quartermaster Corps at Las Cruces, N. Mex., to test fabrics under desert conditions. Other exposure centers are to be overseas, one probably in the Caribbean, the other in the South Pacific for severe tropical conditions.

From the actual weathering experiments, the scientists hope to check the validity of test-tube methods for predicting fabric resistance to rot and mildew. The experiments will also provide the most extensive data ever collected on the actual effectiveness of anti-rot chemicals on cotton cloth.

## Exposed Film Processed By Running Through Wringer

# One-Minute X-Ray Development

► X-RAYS will soon be moving up to battalion aid stations right behind the front lines to help speed our wounded men back to health.

Army and Navy surgeons will be able to locate broken bones and shell fragments and operate to repair the injuries almost on the battlefield, instead of having to evacuate the wounded to hospitals in the rear equipped with dark rooms, developing fluids and special technicians.

This change, along with equal benefits to civilian accident victims and patients undergoing operations, comes from a new X-ray process demonstrated to Rear Admiral Lamont Pugh, Surgeon General of the Navy, and other Naval medical officers at the Naval Medical Center.

With the new process, X-ray pictures can be developed within one minute, instead of the half hour or more now required. They can be developed in daylight, without any fluids or solutions. And because the picture appears on paper, instead of transparent film, no special illumination is needed to examine it. The film holders are designed so they can be used with any conventional X-ray machine in any hospital.

This new process, expected to revolutionize care of the wounded, is based on an invention by Edwin H. Land, scientist-president of the Polaroid Corporation, Cambridge, Mass. Development of it for practical X-ray purposes was done by the Picker X-

Ray Corporation of Cleveland. It was tested by the Naval Medical Field Research Laboratory at Camp Lejeune, N.C., for X-ray use by the armed forces.

The X-ray pictures are taken on polaroid film sheets about 10 by 11 inches. The exposed film sheets can then be run through ringers in a small portable box and within one minute are ready for the doctor's examination. Initial production will be made available to the armed forces.

Use of X-ray machines on shipboard will be greatly facilitated Naval medical authorities pointed out. This is because the new process eliminates the tanks of developing fluid which often spills when ships pitch and roll on rough seas.

In the emergency wards of civilian hospitals, X-rays of accident victims can be made available immediately with the new process, regardless of the time of day or night. At present, patients and doctors often have to wait overnight before the dark room technician arrives to develop the films.

The new process also will greatly speed operations requiring X-rays during the course of the operation. With conventional X-ray methods, patients sometimes must wait on the table under anesthetic for 45 minutes while the X-ray picture is being developed. Risk to the patient as well as time will be reduced with the new, one-minute developing.

## Diborane and Borohydrides Make New Laboratory Tools

# A New Chemical Family

Reprinted from University of Chicago Research Reports

► BASIC RESEARCH asks "How?" and "Why?" and ignores "What for?" But in chemistry the "What for?" often is obvious when the other two questions are answered.

A good illustration is found in work of the University of Chicago's still-active emeritus professor of chemistry, Hermann Schlesinger, which resulted in the development of the compounds known as the borohydrides. From Schlesinger's curiosity about the chemical linkage found in a rare and explosive gas called "diborane" have come compounds valuable as a quick source of hydrogen gas, as reagents in pharmaceutical manufacturing, and with potentialities as high-energy fuels.

The story begins as far back as 1912, when Stock, a German professor, first succeeded in preparing hydrogen compounds of boron, of which the simplest was the gas diborane, chemical formula  $B_2H_6$ . Stock's discovery was considered a major chemical achievement because diborane was both difficult to prepare and dangerous, detonating on exposure to moist air. It took Stock about six weeks of 24-hour-a-day processing to produce about one-tenth of a quart of the gas.

One aspect of diborane was exceedingly interesting to Schlesinger. For some reason the chemical bond in compounds of boron and hydrogen apparently did not follow any of the set rules for ordinary compounds.

Properly to investigate the problem, Schlesinger and his colleagues had first to develop a more efficient method of producing diborane. This they did, making in about one-tenth of the time ten times as much diborane as had been produced by Stock's method. Further research has led to still more efficient methods by which the gas is now readily produced in pound lots for experimental purposes.

With diborane readily available, thorough investigation was undertaken of its properties and those of the other hydrides of boron. There are several different compounds of boron and hydrogen alone. This probing in turn has led to a better understanding of the nature of the chemical bond. In most compounds superficially like diborane, pairs of atoms are held together by sharing two electrons. In diborane, however, too few electrons are available for bonding of this type. Theoretical studies on diborane led to the recognition that, under certain circumstances, a chemical bond may be established by having four atoms (two of which are hydrogen) share four electrons between them. More recently it has been found that this new type of chemical bond exists in compounds other than diborane.

As indicated, among the practical consequences of Schlesinger's work has been the discovery of a new group of chemically useful hydrogen com-

pounds. In contrast to the hydrides of boron discovered by Stock, this new family consists of the borohydrides, and compounds in it contain a metal in addition to the boron and hydrogen.

During World War II, ways were sought of finding a simple method of generating hydrogen in the field, where it could be used for filling meteorological balloons. Compressed hydrogen in heavy steel tanks was too cumbersome to transport. Two of the borohydrides, sodium borohydride and lithium borohydride, were found to be excellent sources for the quick liberation of hydrogen. Because sodium supplies were more extensive than those of lithium, sodium borohydride was selected for this purpose.

Sodium borohydride also is valuable as a reagent in analytical chemistry, as, for example, in the analysis of iron ores. Like the analogous compound, lithium aluminum hydride, also discovered during Schlesinger's investigations, the borohydrides are especially valuable as reducing agents in the field of organic chemistry. One of the common industrial applications of this property has been in the synthesis of vitamin A and other pharmaceutical products.

## Atomic Age

► A SELF-DEVELOPING "atomic dog tag" for soldiers and civilians has been developed by the Army Signal Corps.

A small metal case containing photographic film and a packet of de-

veloping solution, the radiation indicator can be worn around the neck. It measures very slight to fatal doses of radioactivity from an A-bomb attack by discoloration of the film.

Phosphate drinks, given cattle in sections where the soil is deficient in phosphorus, result in more productive breeding and better gains by calves; disodium phosphate and defluorinated triple superphosphate are used.

Aluminum borohydride is interesting to the applied chemist because of its fast reaction time with water. Investigations of the speed of this reaction with water have been attempted, with results indicating it is faster than one-hundredth of a second.

Even more important than the borohydrides themselves is the fact that they have opened up new possibilities in hydrogen chemistry. Hydrogen chemistry can be broken down into three broad fields. One is the chemistry of the acids, in which hydrogen behaves as a positive ion. A second field, equally well studied, has the hydrogen atom behaving neither positively nor negatively. Petroleum compounds belong to this group. The third field of hydrogen compounds is represented by the hydrides in which the hydrogen ion behaves as if it is negative. Until the borohydride compounds were developed, no convenient substances existed for the investigation of this third field. As Schlesinger points out, the chemistry of hydrogen has played an important role in the entire development of chemistry, and the borohydrides open up a new approach to hydrogen.

## "Dog Tag"

## Russia Powerful in Minerals and Mining

# Estimates of Russia's Mines

► RUSSIAN IMPERIALISM plus home development made the Soviet Union the "most powerful and dominating factor" in world mining in 1950.

That estimate was made to the New Mexico Miners and Prospectors Association by George O. Argall, Jr., of San Francisco, editor of the trade publication "Mining World."

He added that 1950 brought Russia "to its greatest economic strength in history" with overall industrial production reportedly 70% greater than in 1940.

The editor told his audience that the Russians, quick to copy American methods and machinery, undoubtedly have duplicated U.S. mining and metallurgical equipment received under wartime lend-lease.

Russia's basic weakness is not a lack of mineral deposits but a lack of plant capacity from mine through to the refinery, Mr. Argall stated.

Other weaknesses cited were a possible shortage of industrial diamonds for making dies and for cutting and polishing, poor transportation from mine to industrial centers and markets, lagging research and development and possibly certain ferro-alloy shortages.

Russia has gained control of important mineral deposits in satellite countries since World War II, including zinc-lead in Poland, copper in East Germany and Bulgaria, antimony in Austria and high-grade

bauxite in Hungary—possibly one of Russia's greatest postwar mineral gains. These deposits are being developed now, Mr. Argall stated.

Other facts concerning the Russian mining position, he said, include:

**Uranium** — Although sources are unknown, recent news of high-grade uranium discoveries in the Ural Mountains may be propaganda to justify decreasing activities in the Joachimsthal areas of Bohemia, Bavaria, Saxony and Czechoslovakia where pitchblende undoubtedly is scarce. However, there have been reported discoveries in other satellite areas.

**Light metals**—Remarkable postwar strides in both aluminum—with last year's production estimated at from 200,000 to 250,000 metric tons—and magnesium.

**Copper**—The goal of an annual output of 255,000 metric tons probably has been reached, with molybdenum recovered as a by-product.

**Coal**—A considerable gain, from 168 million metric tons in 1940 to about 260 million in 1950.

**Manganese**—Production from the war-damaged mines is estimated at 60% of the prewar figure of three million metric tons annually. Russia remains the only major steel producing nation with a superabundance of high-grade manganese ore within its boundaries.

**Chromite**—Superabundance.

*Nickel*—An adequate supply.

*Tungsten*—A strict embargo has been placed on tungsten exports by the Chinese Communists so as to channel it into Russia where a shortage exists.

Mr. Argall also said that Russian steel production has grown from some 18 million metric tons in 1940 to around 26 million tons in 1950.

He said that Russia is supplementing its mining production, and filling in the blank spots, by purchases on the world market.

### Production Low

► THE SOVIET UNION is generally well supplied with minerals in the ground, the American Institute of Mining and Metallurgical Engineers was told at its St. Louis meeting by Paul M. Tyler, mineral technologist of Bethesda, Md.

Russia has made astonishing progress during the past quarter century in expanding mineral production, but it still lacks enough industrial capacity to wage a long drawn-out war on a large scale. Despite impressive gains, the production of minerals in the Soviet Union is less than one-third that of the United States.

Even in agriculture the Soviet Union makes a relatively poor showing in comparison with its population and natural advantages, he stated. Output per worker is far below the American standard in all fields of production and due to the large numbers needed on farms fewer workers are actually available for industry and mining in Russia than in our own country.

Enough is known of the geology of the area under Soviet control to evaluate claims of new mineral discoveries. Virtually all Russia's mineral supply sources are vulnerable to air attack or sabotage. The already inadequate supplies of oil are largely confined to the shores of the Caspian Sea.

Copper production would be dangerously reduced by damage to the principal refinery near Sverdlovsk or to the Kounrad mines and smelter. The Ridder mine, one of the world's greatest mines, is the predominant source of lead and zinc. Even iron and steel output is more highly localized than is generally supposed. It is almost equally divided between the Donets basin of the Ukraine and the Urals plus the recently developed outpost in the Kuznetz basin.

## Unbalanced Equations

### Peron Gas?

► "DURING the thermonuclear reaction," he continued, "we produced gas at terrific velocity which reached speeds of 3,200 kilometers (\$1,984 miles) per second, or about a thousand times faster than the gas expelled by rockets."

—*Washington D. C. Star*

## Shining Meteor in Upper Air Like Heated Front of Rocket

# Heat Transfer in Outer Space

► WHY a meteor shines brightly, as friction with the air heats it to high temperature, is essentially the same problem as the heating of the front of a rocket traveling at one or more miles per second through the upper air. V-2 rockets have been seen to glow dull red as their tips were heated by this atmospheric friction.

The boundary that separates our knowledge of high-velocity rocket ballistics and the astronomers' knowledge of what happens to meteors as they plunge earthward has probably been crossed as a result of investigations still in progress. Dr. Richard N. Thomas of the University of Utah and Dr. Fred L. Whipple of Harvard College Observatory recently described to members of the American Astronomical Society their current joint investigations of astroballistic heat transfer.

These astronomers have calculated the rate of heat transfer in the region where a solid body such as a meteor is just beginning to melt. They find that the transfer varies directly as the air density rather than with the square-root of the density as used in current aerodynamic theory.

The heat transfer is something like ten times more efficient at the high speeds of meteors, which are racing through space ten to forty miles per second when they enter our atmosphere, than at the speeds of our present fastest rockets.

With his associates Dr. Thomas

computes the temperature of the glowing surface of a meteor to be about 3,000 degrees Centigrade when at its brightest.

Further work is being done to determine the maximum size of a meteor that can reach the ground in one piece, this depending partly on the rate of deceleration of the meteor as it falls.

### What Is Temperature?

Dr. Charles Hetzler of Brown University wants a new definition of temperature. He pointed out to those attending the astronomical meeting at Haverford College that astronomers themselves have been guilty of considerable confusion.

Temperature to the man in the street is something he feels by his sense of touch. Actually, it is a result of the transfer to his skin of the energy of molecules in the air or in solid substances. Or it may be received directly from the radiant energy of the sun, a sun lamp, a stove or radiator, or just from the walls of a room.

To a physics student, temperature is proportional to the average kinetic energy of the particles in a given volume of a substance, a gas being the simplest case. Astronomically, the surface temperature of a star is that to which an idealized mass of material, called a "black body," would have to be raised to duplicate the radiation spectrum of that star.

But in the outermost regions of the sun's atmosphere, where the density is that of a vacuum and there couldn't possibly be enough particles to make one feel hot were he located there, astronomers find evidence that the atoms are or have been at one time very hot.

These particles of the sun's corona have lost serious numbers of their outermost parts, or ring electrons. The only way known for this to take place is for such atoms to have been knocked around quite badly at temperatures of millions of degrees known to prevail inside the sun and other stars, or to have been subject to the terrific X-

ray radiation that must accompany such high temperatures at the high densities found in the sun's and star's interiors.

All of which, Dr. Hetzler points out, leaves the concept of temperature in a rather confusing state. Bringing in the concepts of relativity, he suggests that "temperature is a measure of the density, in space and time combined, of the relative motion."

The temperature at a point therefore depends on the total energy of the motion, including atomic, molecular, electronic, and the like, relative to the unit volume about that point per unit time.

### *Carbon Monoxide Detector*

► CARBON MONOXIDE detecting instruments have evolved from unreliable canaries and mice through simple colorimetric devices to practical, continuously operating alarms, indicators and recorders, according to N. W. Hartz of Pittsburgh, Pa.

This expert of the Mine Safety Appliances Company, Pittsburgh, described new gas detecting instruments to the American Institute of Electrical Engineers. The carbon monoxide devices are activated by cells of Hopcalite, a catalyst that speeds up the change of carbon monoxide into carbon dioxide. The process causes a temperature rise. This is measured by a thermopile that sends electrical energy to alarms and recorders.

The demand for detectors of air pollution has led to the development of instruments to show danger that may come from undesirable gases from industrial plants and other

sources. He described instruments to detect poisonous and flammable gases.

Present combustible gas detecting instruments have been simplified to the point where they are composed essentially of an electrical Wheatstone bridge in which a sample is drawn over a heated catalytic filament so that any combustibles present are burned upon contact with the hot wire.

Raising the temperature of the filament, Mr. Hartz stated, increases its electrical resistance in proportion to the percentage of the lower explosive limit concentration. Portable instruments of this type are powered by flashlight dry cells.

At the same meeting W. E. Belcher, Jr., of the Minneapolis Honeywell Instrument Company, described a device that detects unsafe temperatures in rotating machines, particularly in bearings. This new instrument is now about to emerge from the laboratory.

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## Chemists Improve Common Materials

# Chemical Patents

Copies of complete specifications may be ordered from the Commissioner of Patents, U.S. Patent Office, Washington 25, D.C. Order by patent number and remit 25 cents for each patent, by money order or Patent Office coupon, not stamps.

### Acid Cement from Gypsum

► INDUSTRIALLY important sulfuric acid and portland cement are obtained from gypsum in a process on which a patent was recently issued. In a special process suggested by the inventor, phosphate rock may be added to be converted into a superphosphate by the acid formed. This superphosphate is a valuable fertilizer.

Gypsum is calcium sulfate. In the process it is converted into lime, which is calcium oxide, and sulfur trioxide which, combined with water, is sulfuric acid. The acid-cement-producing method uses a material such as silicon dioxide or aluminum oxide together with gypsum and a coke containing a catalyst. The result is sulfuric acid and a good grade of hydraulic cement in sufficient quantity to off-set the cost of making the acid. Inventor of the process is Robert M. Willson, Victorville, Calif. Patent 2,528,103 was awarded to him.

### Superphosphates

► A PROCESS for making superphosphates from phosphate rock and phosphoric acid, instead of the more usual sulfuric acid, brought patent 2,528,514 to Stewart A. Harvey, Sheffield,

Ala., and Grover L. Bridger, Ames, Iowa. Rights are assigned to the federal government as represented by the Tennessee Valley Authority.

Phosphoric acid is already in use in some processes of making a superphosphate but these methods are carried out in batch-type mixers with considerable time consumed. This new process is claimed to be a cheap, dependable method for continuously mixing finely divided phosphate rock with phosphoric acid, which may be operated for long periods of time without a shut-down and which requires a minimum of attention.

### Natural Gas in Tanks

► NATURAL GAS in pressure tanks for use in isolated sections for household purposes is promised with an improved liquefaction process which condenses the methane and other combustible constituents but eliminates the noncombustible nitrogen. Walter H. Rupp, Mountainside, N. J., received patent 2,529,312 for the process. Standard Oil Development Company has acquired the rights by assignment.

### Chemical Fluids for Pumps

► NEW CHEMICAL fluids for pumps which produce the extremely high vacuums needed in science are the invention of Melvin J. Hunter of Midland, Mich. Rights on patent 2,530,356 are assigned to the Dow Chemical Co. The pumping fluids, called organo-siloxanes, boil at temperatures in which the pump operates. Extreme-

ly stable, their vapors trap and remove gases from equipment to be evacuated in a process known as condensation pumping.

### Peat for Heat Insulating

► AMERICA's deposits of bog-moss peat can be made into heat-insulating materials for use in buildings when processed by a method for which two Norwegian scientists were granted patent 2,529,335. They are John Gunderson Helland and Ragnar E. L. Moen, both of Skien, Norway.

The process includes tearing the raw peat into pieces, heat treatment and washing, followed by kneading in a special machine which puddles the material without tearing the fibers. Following this the material is transferred to a press in which the mass is given a desired shape. Pressing is unnecessary if the treated peat is to be used for insulation in a mass of loose fibers. Then, only drying is required.

### Improved Synthetic Rubber

► BETTER quality synthetic rubber is obtained by a process of adding calcium silicate to the rubber mixture, the chemical acting as a reinforcing pigment which improves the strength and abrasive qualities of the rubber compound.

Patent 2,532,665 was issued to Frederick W. Gage, Akron, Ohio for this invention. Rights have been assigned to the Pittsburgh Plate Glass Company, Pittsburgh, Pa.

The use of calcium silicate in rubber compositions is not new but in older processes the products have a tendency to be sticky and cause difficulty in milling operations. This stickiness is greatly reduced in the

new process. It is carried out by the addition of a small amount of a carbonic acid ester to the butyl rubber-calcium silicate rubber composition.

### Air Pollution Reducer

► THERE WILL BE purer air in the vicinity of industrial plants from an improved apparatus for cleaning stack gas. It is designed for placement at the top of the stack and for the removal of dust, fly ash and sparks from the discharge. It is particularly for use with a cupola stack. In it a swirling movement of the gas is created by fresh air introduced under pressure, this air containing water sprayed into it.

Patent 2,529,045 was issued to Raymond C. Ortgies, Chicago, the inventor. Rights have been assigned to Whiting Corporation, Harvey, Ill.

### Automobile Antifreeze

► NO RUST will form in the radiator with an improved anti-corrosive antifreeze composition, suitable for use in automobile and other internal combustion engines. The preparation brought patent 2,534,030 to Edwin H. Keller of Wawa, Pa. The patent has been assigned to E. I. du Pont de Nemours and Company, Wilmington, Del. It is claimed to be an antifreeze superior from the standpoint of inhibition against corrosion, precipitate-formation and foaming tendency.

The basis of this antifreeze is the commonly used ethylene glycol, an alcohol with a high boiling point. To this is added water and less than 7.5% by weight of alkali metal metaborate corrosion inhibitor. This latter is said to be superior to the tetraborate-phosphate compositions in more or less general use.

## Radioactivity Container

► A CONTAINER in which radioactive materials from atomic energy piles can be carried safely by handlers brought patent 2,533,102 to John F. Gifford, Richmond, Calif. Rights are assigned to the U. S. Atomic Energy Commission.

Radioactive substances produced at government atomic laboratories are

now being widely used in industrial, hospital and university research work throughout the country. Shipment in ordinary containers might cause severe harm to persons coming near them. This container provides a shield against radioactivity. It has within it a number of tiny trays, each pivoted separately so that contents can be removed while other trays remain within the shielding material.

## *Little World Without Radioactivity*

► A LITTLE WORLD where there will be no dangerous radioactivity, no atomic bomb by-products, is now being created. It is peopled by highly pedigreed mice, rats, rabbits and guinea pigs. But humans exposed to dangerous radiation at work or in any future atomic bombings will benefit.

The radioactivity-free oasis is being established at the Jackson Memorial Laboratory at Bar Harbor, Maine. Its unique reversal of present trends at medical research laboratories was announced by its director, Dr. Clarence C. Little.

Our object is to develop for research throughout the United States, Canada and Europe a source of experimental material which at any time can be guaranteed to be a normal control population for a group of animals being used elsewhere, Dr. Little stated.

Radioactivity can permanently change living cells, among them the reproductive cells from which all future generations are formed. In order to understand such changes, to foresee them, to prevent, direct or evaluate them it is absolutely essential

to have control animals completely isolated from any source of radioactivity or atomic energy. Radioactive isotopes are now being used in more and more laboratories in a search for cancer cures and in a search for better means of fighting atomic energy damage.

Results of use of a radioactive chemical in cancer must be compared with the course of the cancer in animals untreated. But if the ancestors of these untreated animals had been exposed to radioactivity through living in the laboratory where the chemicals were being tested, they would not give an accurate control to compare with the treated animals.

Besides excluding all radioactive isotopes or animals treated with them, the Jackson Laboratory will have special isolation rooms and units where any chemicals with cancer-causing properties will be used.

The laboratory, long famous for its specially bred strains of animals for cancer and other research, has rebuilt the laboratories and re-established the animal colonies that were largely destroyed by forest fire a few years ago.

## For the Home Lab

# SULFUR

by BURTON L. HAWK

► THROUGH its evil-smelling compounds, sulfur has gained a rather bad reputation. Although many sulfur compounds do yield an offensive odor, the element itself is odorless and tasteless.

Despite the bad smells, sulfur is an extremely useful substance. One of its compounds, sulfuric acid, is the most useful chemical substance ever manufactured. About 10,000,000 tons of it are consumed each year in the United States alone. Another important use of sulfur is in the vulcanization of rubber. It is also used in fungicides, gunpowder, fumigants, and in the manufacture of hundreds of important compounds.

Sulfur has been known since the dawn of history. It was used as a fumigant and in medicine as early as 1000 B.C. It is the "brimstone" of the Bible.

### Allotropic Forms

*Rhombic Crystals.* Sulfur exists in two allotropic crystalline forms, the most stable of which is the rhombic.

Dissolve about 0.5 gram of sulfur in 4 cc. of carbon disulfide. If necessary, filter the solution. Pour the clear filtrate in a watch glass and allow to evaporate spontaneously. Do not heat. Examine carefully the crystals that remain. Note the formation—like two pyramids base to base.

*Monoclinic Crystals.* Heat gently a small amount of sulfur in a dry test

tube. Heat until the sulfur just melts to a thin, light amber colored fluid. Be careful not to overheat. Pour the liquid into a dry filter paper in a funnel. As soon as a portion of the liquid begins to solidify, quickly pour off the excess liquid. Open the filter paper and examine the crystals with a magnifying glass. Note this time they are long, transparent and rectangular shaped.

*Amorphous (Plastic) Sulfur.* Heat again about one gram of sulfur in a dry test tube. It will melt to the amber-colored fluid. Continue heating. The liquid will turn dark orange and finally into a black mass. Continue to heat until the mass is again fluid and just begins to boil. Then pour quickly into a beaker of cold water. Do this carefully, as the vapor may ignite. Examine the mass in the beaker. You will note that it is plastic and elastic, similar to rubber. However, this condition is not permanent. Upon standing it becomes brittle and returns to the rhombic form. The strange part of it is that in this condition, sulfur is not soluble in carbon disulfide. Also, a minute trace of sulfuric acid must be present in the sulfur in order for it to be plastic. Absolutely pure sulfur does not form the plastic allotropy.

*Colloidal Sulfur (Milk of Sulfur).* Colloidal sulfur consists of small rhombic crystals. It is formed readily by adding a few drops of hydrochloric

acid to a solution of sodium thiosulfate. When the acid is first added, nothing appears to happen. Then, after a few seconds, a white color is suddenly formed which rapidly develops into a yellow precipitate of colloidal sulfur.

### Sulfides

Sulfur combines with most of the metals and many of the non-metals to form sulfides. Here are a few of them:

*Iron Sulfide.* Heat equal portions of powdered sulfur and iron filings in a metal crucible or lid. Heat until the sulfur ceases to burn. The remaining mass is ferrous sulfide.

*Hydrogen Sulfide.* Break up a few lumps of the ferrous sulfide just prepared. Place in a test tube and add dilute hydrochloric acid. You will soon recognize the rotten-egg odor of hydrogen sulfide.

*Zinc Sulfide.* The formation of zinc sulfide is accompanied by a pyrotechnical display. Mix together two parts of powdered zinc with one part of sulfur. Use small quantities. Place the mixture in a neat pile in a large metal pan. It can now be ignited by touching it with a hot glass rod. Keep your distance! Sometimes, the sulfur alone is ignited and burns quietly with a blue flame. Even so, be patient and still keep your distance. The mixture will suddenly, without warning, burst into a brilliant and violent green flame accompanied by large clouds of white smoke. To avoid all danger of fire, perform this experiment outside, or on the concrete floor of the basement.

*Mercuric Sulfide.* It is not even

necessary to apply heat to obtain mercuric sulfide. Simply grind together a small globule of mercury with a little sulfur in a mortar. A black amorphous powder is obtained. However, if the two elements are heated together, the red variety of mercuric sulfide (vermillion) is obtained.

### Oxides

As you probably have observed by now, sulfur burns in air with a blue flame forming *sulfur dioxide*,  $\text{SO}_2$ . And as you have probably noticed by now, the latter has a pungent, irritating odor. Sulfur dioxide is a very interesting and useful compound and we will investigate its properties more thoroughly at a future date.

When sulfur dioxide is interacted with oxygen, by means of a suitable catalyst, *sulfur trioxide*,  $\text{SO}_3$ , is obtained. It is a white solid which dissolves in water to form sulfuric acid. (See CHEMISTRY — August, 1946, page 35).

Other oxides of sulfur have been isolated. If you are interested, they are the *monoxide*,  $\text{SO}$ , a gas formed by the action of an electric discharge on sulfur dioxide and sulfur vapor at low pressure; the *sesquioxide*,  $\text{S}_2\text{O}_3$ , a blue-green solid; and the *heptoxide*,  $\text{S}_2\text{O}_7$ , a thick liquid.

\* \* \* \* \*

Of course, the foregoing has been merely an introduction to sulfur. Its many compounds are far too numerous to be covered at this time. We will, from time to time, discuss other important compounds of this most useful element.

Now, we suggest that you go outside and get a breath of fresh air.

**Chance Results Lucky  
For Alert Researchers**

## Serendipity

by ROGER ADAMS

*Head of Department of Chemistry, University of Illinois*

► I HAVE CHOSEN as a title for my remarks "Serendipity." The word has existed since 1754 when the English politician and man of letters, Horace Walpole, proposed in a letter to Horace Mann the adding of a new word to our vocabulary, "serendipity." Horace Walpole's suggestion arose after reading a fairy tale, entitled "The Three Princes of Serendip." Serendip was the ancient name of Ceylon. "As their highnesses travelled," so Walpole wrote, "they were always making discoveries, by accident or sagacity, of things they were not in quest of." The term serendipity is not found in abridged dictionaries, but in those dictionaries where it appears it is defined as the happy faculty, or luck, or finding unforeseen evidence of one's ideas or, with surprise, coming upon new objects or relations which were not being sought. It is a word seldom used by science writers and should be in their vocabularies since it is so descriptive of the way in which most of the important discoveries, past and present, in pure and applied science have been made.

In modern research, the best program that has ever been devised on paper has never functioned from beginning to end as expected. Only rarely do investigations yield the products which are sought. Repeated failures to reach an objective are very

common. The ratio of negative experiments to positive ones in every phase of each research project is exceedingly large. If this depicts accurately what takes place in a research laboratory, you may well inquire how discoveries are made if they are not preconceived. During the course of a well-planned program, experiments are performed in one of its phases which do not give the expected results. These results, however, serve as a lead toward the solution of some entirely different unsolved problem of academic or industrial interest. The original project may be continued or it may be dropped but a new project is started on the basis of the unexpected results. In most cases, the new project is more likely to succeed than the original. Under any conditions, a new line of research is stimulated which in turn may be carried to completion or during its course still another observation may be made to suggest an additional avenue of fruitful investigation.

Perhaps the most remarkable instance of accidental discovery was the finding of the Western Hemisphere by Columbus. He sailed West from Spain with the conviction he would find a shorter route to the East Indies; unexpectedly, he encountered a whole new world. Although he was unaware of the significance of what

he had found, he realized he had had a remarkable experience and, by extending the knowledge of what he had done, he laid a course which others followed.

In the annals of scientific research, this happy use of good fortune has been conspicuous. The origin and development of electrical phenomena from which followed the telegraph, telephone, and radio broadcasting, were all based on accidental beginnings. In the growth of electrical science, serendipity has played an unusually important role. The relation between electricity and magnetism was discovered by pure chance when at the end of a lecture the Danish physicist, Oersted, happened to bring a wire which was conducting a strong current to a position above and parallel to a poised magnetic needle. He had previously demonstrated, by intent, that when the wire was held perpendicularly above the needle nothing happened. However, now when the wire was held horizontally over and along the needle's length he was astonished to note that without any visible connection the needle swung around until it was almost at right angles to its former position.

With quick insight, he reversed the current in the wire and found the needle then deviated in just the opposite way. Later, Faraday confirmed the report that an electric current in the wire can move a magnet but also demonstrated that a moving magnet can cause a current to appear in a wire. From these original, relatively trivial observations has evolved our vast modern electrical industry with its immense generators and its ingenious arrangements for distributing

power to run our automatic machines, air-conditioners, and many household appliances.

Charles Richet, the French physiologist, discovered what we now speak of as anaphylaxis or allergy. It concerns those substances which may, after initial exposure of the individual to a substance, later become poisonous to the victim. He was testing an extract of the tentacles of a sea anemone on laboratory animals in order to learn the toxic dose. When animals, which had readily survived that dose, were given after a lapse of some time a much smaller dose, even as low as one tenth, it proved fatal. He had discovered induced sensitization.

Immunization was discovered by chance. Pasteur had used an old and discarded bacterial culture to innoculate fowls. They became ill but survived. This experiment led Pasteur to believe that by using first cultures of low virulence and then repeating with cultures of greater virulence the animals could be made to develop resistance to infection gradually. His expectations were fulfilled. By this procedure he was able to immunize humans against rabies.

While studying the functions of the pancreas in digestion, Mering and Minkowski removed the organ from a number of dogs. A laboratory assistant noticed the swarms of flies around the urine of these animals, a fact which he mentioned to the investigators. The urine was found to be loaded with sugar, thus indicating that experimental diabetes had been produced and the first glimpse was given into the cause of that disease. It is now known that small islands of cells in the pancreas produce an in-

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ternal excretion which controls the use of sugar by the organism and that, if these cells are damaged, sugar metabolism is disrupted. Insulin is an extract of these cells and is used for relieving the diabetic sufferer.

The discovery of Vitamin K, which, if deficient in an individual, prevents his blood from coagulating properly, was made by Dam, a Danish investigator, while studying the chemical changes in a certain fatty substance in chicks. On a specially restricted diet, the chicks often suffered extensive internal hemorrhages, but when the diet was changed to seed and salts, the bleeding failed to occur. A substance, later designated as Vitamin K, which occurs in many cereals, certain vegetables and in the liver fat of swine, was eventually isolated and synthesized for use before surgery in those individuals who have a Vitamin K deficiency.

Other historic examples of serendipity are numerous; the discovery that the circulation of blood into different parts of the body is governed by the nerves; Nobel's discovery of dynamite; Perkins' discovery of coal tar dyes; the exploration of the whole realm of deficiency diseases arising from the unanticipated observation that removing the covering from the kernels of rice causes beriberi in those who depend on rice for food.

The discovery of penicillin has been described in many popular articles. I hesitate to make more than a few remarks about it, but it is one of the most important discoveries of our time. In a Petri dish containing an agar medium, Alexander Fleming was growing pus-producing bacteria for some of his researches. Spores of

a mold by chance landed on the agar. Here it multiplied so that when the investigator returned after an absence of some time he found a round spot of white mold. The average scientist might merely have washed out the Petri dish, condemned his luck for the mold contamination and have started a new growth of bacteria.

Fleming, however, observed that around the spot of mold there was a narrow ring of agar which was perfectly clear in contrast to the balance which was cloudy due to the presence of the living bacteria. He permitted the mold to grow further and observed that as it did so the clear ring around it expanded with the growth. He concluded that in the growth of the spores there was being formed some chemical substance which was killing the bacteria. This observation was reported. In due time, chemists undertook to isolate and determine the character of the chemical substance formed. It required ten to fifteen years to complete the experiments which established penicillin as a pure non-toxic and highly bactericidal entity.

The late Ira Remsen, President of Johns Hopkins University, who was at the time Head of the Chemistry Department, had a student studying the oxidation of certain substituted benzene derivatives. Several products had been isolated and were being investigated. A trace of one of these products became attached to the point of a lead pencil which the student happened to touch on his tongue. He observed a phenomenally sweet taste. He had discovered saccharine.

Another sweetening agent now marketed as "sucaryl" was discovered

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by Michael Sveda, a student at the University of Illinois, while working under the direction of Dr. L. F. Audrieth on sulfamic acids and their derivatives in the hope of finding a new analgesic. While smoking one day he noticed a very sweet taste on his cigarette. Apparently a small amount of one of his products had become attached to a finger and was transferred to the end of his cigarette which he placed in his mouth. Sucaryl is not as sweet as saccharine but it has the advantage of a more pleasant taste. It is stable at cooking temperatures in the presence of acid or alkaline materials in foods while saccharine decomposes under these conditions.

In my own research experience of over thirty-five years, I have had several instances of unexpected reactions which have revealed results of more interest and value to the organic chemist than might have been achieved by the original investigation. I shall cite one example. Just thirty years ago, I had assigned a student the problem of producing a finely divided platinum catalyst, commonly called platinum black because of its color, which would be uniform in its activity and effectiveness in causing hydrogen to combine with various types of unsaturated organic compounds. A catalyst, you recall, is a substance which does not take part in a reaction but has the phenomenal ability to greatly speed up the reaction between two chemicals that otherwise would combine so slowly they could for all practical purposes be said not to combine at all. Prior to the start of this investigation, it had been known for twenty or more years that very finely divided platinum

formed by precipitation from a solution of platinic salt was an effective catalyst but no method of preparation was available which always gave a product of maximum activity. The procedure described by Professor Richard Willstätter was accepted as the most reliable at that time. Willstätter's process was tedious and required four or five days of experimentation before the catalyst was ready for use. In our hands, the product as obtained in successive runs by this method, each carried out presumably under identical conditions, exhibited a wide variation in activity.

We worked for a year and a half modifying the operation and finally were convinced that we had improved it to the point where a far better catalyst would always result. The student was then permitted to prepare a relatively large amount of the catalyst in one experiment. An ounce of chloroplatinic acid was used, an expensive item for a university laboratory. Before he had the experiment half completed, the porcelain casserole used as a container cracked and broke. The platinum in the form of a suspension in an alkaline medium flowed over the top of the wooden laboratory desk which was old and badly corroded by long use. The student, knowing the value of the material, immediately scraped up the platinum with a knife as best he could. Wooden splinters and a pigmented organic coating on the wood contaminated the recovered platinum. Experiments to obtain the platinum pure were then considered and devised. The impure platinum was treated with a mixture of concentrated hydrochloric acid and nitric acid which is a solvent for this metal.

A solution resulted, but it was black instead of orange because all of the organic material had not been destroyed. In order to remove the balance of the organic material a promising approach appeared to be the addition of the strong oxidizing agent, sodium nitrate, to the black solution, followed by evaporation and fusion. During the fusion which was apparently effecting the results desired, a heavy brownish powder separated from the melt and settled to the bottom of the casserole. This was unexpected. The brown material was insoluble in water and the sodium nitrate used as oxidizing agent was readily washed away. All of the platinum had precipitated.

Further investigation revealed that this product was a dioxide of platinum, a derivative which had previously not been described. Naturally, one of the first tests made upon this product was its properties as a catalyst. It was found that when it was shaken with hydrogen, the oxide was decomposed immediately and a very finely divided platinum black resulted. Subsequent preparations were made very simply by fusing sodium nitrate with pure chloroplatinic acid. A plantinum black catalyst of constant activity and more effective for hydrogenation than any finely divided platinum previously prepared resulted. No method equal to this for preparing platinum black catalyst has been discovered since. The catalyst is widely used and is available in every organic research laboratory.

In the Kaiser Wilhelm Institute for Medical Research in Heidelberg, the investigation of chemicals affecting the copulation of male and female gametes of *chlamydomonas* (green

algae) was being made. In one of several laboratory dishes in which identical copulation experiments were underway, copulation suddenly stopped. Upon observation, it was noted that a particle of tobacco had dropped into the dish from the stem of a cigarette resting on a ledge above the table. Immediately a careful study was made of the various chemical constituents of tobacco. One of those present in very small amounts, known as rutin, proved to have the same inhibiting action as the tobacco itself. A discovery of fundamental scientific interest had been made. The most fantastic part of this discovery was that rutin occurs only in green tobacco and is destroyed when tobacco is cured. It was during the war period when only green tobacco was available in Germany and it was a cigarette of this kind that the investigator was smoking.

In order that you will not get an erroneous impression that all research must involve unusual luck, I shall cite one development based on a well-planned project in which serendipity played a relatively minor part in reaching the final goal. The story of the discovery of nylon falls in this category. The late W. H. Carothers initiated a problem to find laboratory methods by which certain simple molecules, called monomers, could be converted into giant molecules, called polymers, similar to those so readily produced in nature. In animal and vegetable life such substances are found in abundance; wool, silk, starch, cellulose and rubber are some of the important ones. Such molecules have a certain chemical resistance and stability not found in simple compounds.

His researches were successful and by ingenious quantitative experiments using procedures which were new at the time, methods were achieved for synthesizing giant molecules. The products were opaque, thick, viscous masses. By heating one of these until it was soft, forcing it through minute perforations in a metal disk, and then cooling, filaments of the material could be obtained. These, however, did not have the strength of natural fibers and they had an undesirable stretching property. At this point serendipity helped. In a beaker containing one of these products as a very thick mass which had cooled to room temperature, a stirring rod had been left. The rod was stuck and required a real pull to release it. The polymer adhered to the rod and stretched out like molasses candy. It was noticed by the experimenter that as the rod was drawn further and further away the adhering thread of polymer was obviously changing in physical appearance and indeed in properties as was found later. The molecules by this process were being oriented as they are in natural fibers. The operation was termed "cold drawing."

Cold drawing was found to be essential in order to convert the polymeric material into a product with high tensile strength. Attention was then turned to applying these discoveries to the synthesis of molecules which might resemble closely natural molecules. The result was nylon. No chemist could have predicted precisely what the properties of these giant molecules would be and that nylon would be found. But if the methods for producing large molecules similar to those found in nature could be

developed, there was reasonable assurance that somewhere in the area there would be discovered a substance of commercial importance.

The director of one of the largest and most efficient industrial chemical research laboratories in this country with an annual budget of several million dollars estimated that ninety-five per cent of the discoveries of his unit are the result of serendipity in one degree or another. It is noteworthy also that his records indicate one substantially profitable discovery to the company from the services of two Ph.D. chemists for thirty-five years each or the services of one man for seventy years. In other words, from a laboratory of seventy capable Ph.D.'s, an average of one important discovery a year may be expected. These figures serve to impress upon a lay audience that discoveries require time, skill and money for accomplishment.

From my remarks non-scientists might well deduce that important scientific discoveries are the result of sheer luck and they might just as likely have been made by mediocre scientists as by more skillful ones. I do not deny that luck is involved, but such luck happens to the scientist who is observant, who knows how to interpret unusual results, and can foresee new applications. Quite as important as serendipity is the presence of a prepared mind. A chance discovery involves both the phenomenon observed and an appreciative, intelligent and well-informed observer. Statistically, important discoveries in pure and applied science rarely emanate from the hands of scientists who do not have a substantial record of past achievement.

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## Morphine Superseded By New Synthetic Drug

# Methadone Relieves Pain

► OUR WOUNDED men in Korea have been getting a new pain-relieving drug so good that the "pain just floated away on a cloud," as one of them said.

This pain-killing drug was given to hundreds of wounded Marines during the fighting just before evacuation from Hungnam beachhead and while recovering from operations in the Army General Hospital in Tokyo.

Results were so good that Army and civilian medical authorities are now convinced that we need never again fear any shortage of pain-killing drugs such as morphine.

Morphine comes from opium from poppies. China, now Red, is one big source. But the new pain-killer is a synthetic drug made from cheap, common chemicals called nitriles. Its name is methadone. Grain for grain, it is the exact equivalent of morphine in relieving pain. There is plenty of it now and it can be made in any needed amounts.

"There is no longer any necessity for stockpiling morphine," Dr. Henry K. Beecher, professor of anesthesia at Harvard and chief of the anesthesia

department at Massachusetts General Hospital, declared. "I don't make statements like that lightly," he added.

Dr. Beecher, civilian consultant to the Surgeon General of the Army, has just returned from Korea where he saw the results of methadone in relieving steady, bad wound pain. They bear out a three-year careful trial of the drug on civilian patients at Massachusetts General Hospital.

Methadone was developed in Germany during World War II at the I. G. Farbenindustrie. Our Army, heretofore always concerned over a possible shortage of morphine, pushed trials of it in cooperation with the National Research Council and the National Institutes of Health. The methadone used in Korea is a new form, called iso-levo. It causes less nausea than the racemic form which is now on the market. It has addiction properties and its sale is therefore controlled under the federal narcotics law. But besides its pain-relieving quality, methadone can be used as a substitute for morphine to withdraw that drug from morphine addicts.

New Jersey, with 15% of all chemical manufacturing plants in the United States, 26% of the salaried employees in the chemical group, and over 20% of the wage workers, leads the nation in the production of chemicals.

A plastics rivet, with peculiar advantages in certain jobs, is ballooned out after placement with compressed air to make it hold; the rivet is center-bored through the head to near its end for the air-application, and is installed hot.

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